INITIAL ASSESSMENT SURVEY OF THE DOE LEHR SITE OF UNIVERSITY OF CALIFORNIA — DAVIS

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CONTRACT: DE-AT03-84SF15160 ISSUED: 31 OCTOBER 1984

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1.0 INTRODUCTION

1.1 PURPOSE

An initial assessment survey of the Laboratory for Energy Related Research (LEHR) located on the University of California, Davis campus was undertaken by Rockwell staff under DOE Contract DE-ATO3-84SF15160. The purpose of the survey was to obtain data and perform an initial characterization of the nature and extent of radioactive and chemical contamination at the LEHR site. The survey was an exploratory survey to determine the presence of radiological or chemical contamination which could either migrate to the environment or present an unanticipated cost in the decontamination and decommissioning of the LEHR facility.

1.2 BACKGROUND

Prior to the start of the onsite survey, a preliminary visit was made to the site by D. L. Speed of Rockwell and C. A. Taylor of the San Francisco Operations Office of DOE. This trip was made to help in the writing of the survey plan. A survey plan for the initial assessment survey of the LEHR facility was drafted and approved by DOE-SAN prior to start of work at LEHR.

This initial characterization survey was performed in accordance with the prepared plan (NOOISRR130013) which was submitted to DOE SAN for review and concurrence. The plan, funding, and schedule were adequate for an "initial" characterization survey only. A full and complete characterization survey was not planned and was not performed.

1.3 SUMMARY RESULTS

The results of the surveys performed are summarized in Table 1.3.1. No indications were found of gross contamination in unanticipated areas. Contamination was found in radium injection wells, radium septic tanks, and in

two bore holes drilled in the burial ground areas. The levels detected were within two orders of magnitude of background; however, the potential exists for migration of material from these areas.

No hazardous quantities of chemical contaminants were noted in samples from the LEHR site.

TABLE 1.3.1
SUMMARY OF RESULTS

	Area	Type of Survey	Results
4.2 <u>Sur</u>	rface Features		
4.2.1	General Surfaces	Gross α B Y	No unexpected fields. Y detected at Co-60 irad field and AH-1 storage area.
4.2.2	Statistical	Gross a B	Essentially free of contamination.
4.2.3	HVAC (AH-2 and -2 Buildings)	Smear samples α and β meters	Two elevated readings less than typical action levels
4.2.4	Surface Soil	Gross α and β	No indications of contamination attributable to the LEHR operations.
4.2.5	Field Drain Survey		Not accessible for survey.
	(Discharge to Putah Creek)	Gross α and β soil samples	No activity above normal background.
4.2.6	Dog Pens	Gross α and β soil samples and gross and β	No measurable contamina- tion found.

TABLE 1.3.1
SUMMARY OF RESULTS (Continued)

	Area	Type of Survey	Results
4.3 <u>Sub</u>	surface Features		
4.3.1	Burial Ground and General Area	Gross and B	No increased β . Sharply increased γ in holes 13 and 14, C-14, Sr-90, Ra-226, and H^3 .
4.3.2	Leach Feld	Bore holes	No increased activity.
4.3.3	Radium Injection Wells	Gross and	α and Υ contamination on manhole covers.
4.3.4	Radium Septic Tanks	Radiochemical analysis of sludge for Pu-241	No activity found.
4.3.5	Imhoff Facility Settling Tanks	Same as above	No measurable quantities?
	Surfaces	Smear for gross α and β .	Low levels of removables found.
4.4	Radiochemical Analysis		C-14, Ra-226, Sr-90, and H-3 identified at relative levels.

1.4 RECOMMENDATIONS

This initial survey found no indication of gross contamination in unanticipated areas nor evidence of significant migration of contamination. However, available records and information did not establish a high degree of confidence that potentially contaminated areas had been adequately identified. The scope, schedule, and budget for the initial survey was adequate only to investigate the most suspect areas.

A full characterization study and survey is recommended to identify the nature and extent of contamination over the entire LEHR site (especially the formerly utilized waste disposal sites) as well as in the facilities currently using and storing radioactive materials.

2.0 SITE DESCRIPTION

2.1 LOCATION

The LEHR facility is located on the campus of UC Davis approximately 1/2 mile south of Interstate 80 on County Road 79 in Solano County. The southern border of the facility is a levee on the north side of Putah Creek. The eastern boundary has changed several times over the course of expansion of the research programs. Please refer to Figure 2.1, which shows the current boundary of the site.

2.2 SURFACE FEATURES

Figure 2.2 shows the major LEHR facility structures. Nearly all of these structures have been used to either store, administer, measure, or otherwise utilize radioactive material at one time or another in the history of this facility. The areas with the greatest inventories of radioactive materials are the A H I and INHOFF buildings. The initial assessment survey did not seek to measure contamination in any of the LEHR. structures.

2.3 SUBSURFACE FEATURES

There are numerous subsurface features associated with the LEHR facility with the potential for contamination by radioactive materials. A number of these features are known to be contaminated, and it is not known if the contamination has spread from these structures. In two cases (see Sections 4.3.3 and 4.3.4), it is conjectured that some sort of leakage has occurred in the past which may have resulted in a spread of radioactive contamination. Other features were found on drawings but could not be confirmed by physical examination in the initial assessment survey. Some of these subsurface features (notably burial sites of chemical and radioactive waste) are associated with the LEHR facility activities, while some may have been in place prior to the acquisition of the land by the LEHR facility. As documentation of the exact

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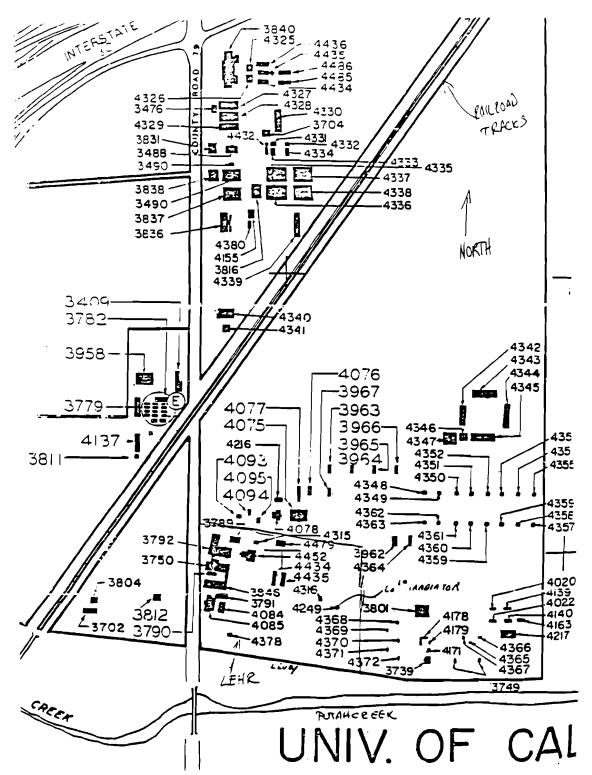


Figure 2.1. Location of LEHR Site

MALL T PECENMA B BUSSINESS STORAGE TAB U FERVICE STANCE Marenach Eugega - Bereag Eugega - Bereag Eugegalosa (or вно• — **К**-Figure CELLULAR CELLULAR MAIN OFFICE & LABORATORY TEL: (010) 752-1541 2.2. PENS SERIATRICS В AUX R Major LEHR Facility Structures 2 1 INHO! P M N * H S D E E JCLMC sec res F' WA SHOOWN

AI-DOE-13504

dates and locations of these features has not been obtained, it is expected that these burial sites may become a matter of interest in the future.

2.4 SITE ACTIVITIES

2.4.1 Pre-LEHR Activities

Prior to the dedication of the described portion of the UC Davis campus being designated as the LEHR facility in the early to mid-1950s, the land was used for a number of purposes. While an exhaustive historical research effort was beyond the scope of this effort, some time was spent in search of the use of the land just prior to the LEHR era. Conversations with Dr. Goldman indicated that the first area of land given to LEHR had been the campus garbage dump.

As the level of research at LEHR increased, more room was needed, and the size of the facility was increased in several stages.

As the LEHR facility was growing to the east, it appears that the university waste disposal operation was moving eastward at the same rate. This waste disposal operation involved the burial of chemical, radioactive, and other undocumented types of waste. A certain amount of survey time was spent in an attempt to track down some of these activities without success. There appears to be a lack of available documentation in relation to the university disposal of chemical waste at that time. The level of documentation of radioactive waste disposal was better than the chemical data, but did not preserve much information for the future. Reproductions of two unnumbered blueprints are in the hands of DOE-SAN. Due to their large size, they could not conveniently be included in this report.

2.4.2 Past LEHR Activities

For the convenience of the reader, this phase of the site activities description is broken down into two subcategories, research and waste disposal.

2.4.2.1 Research

There has been a great deal of diverse research at this facility. In this initial assessment, we were able to focus only on the major programs. Detailed information concerning the radioactive materials used in past programs is difficult to reconstruct at this time because of the lack of accurate records and normal personnel turnover. While some records do exist, they do not show the detail desirable from a survey viewpoint.

The primary programs of research involved Ra-226 and Sr-90 deposition in small animals. Primary references to this effort may be found in Appendix A.1 (reprints from Health Physics, V.46) of this report.

These papers represent a portion of the work that was carried out in this facility.

2.4.2.2 Waste Disposal

There appears to be a lack of available documentation concerning the history of waste disposal at by the LEHR facility. The reader of this document should keep in mind that this is not an uncommon state of affairs for an older facility that has used radioactive materials.

The following information was related to the ESG personnel by various LEHR staff. Recollections from many years ago resulted in statements that were incomplete and inconsistent. At least three onsite waste disposal schemes were found in our cursory search through the prints that were reviewed.

2.4.3 Present LEHR Activities

2.4.3.1 Research

The present level of research at LEHR appears to be greatly reduced from the recent past. While it was not a part of the original initial assessment

survey plan, some time was spent investigating the current projects. Information on this was gathered on an informal basis from the LEHR personnel with whom we had contact.

2.4.3.2 Waste Disposal

These efforts were not investigated in detail for compliance with current regulations and standard practices but do appear to be up to current standards.

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3.0 CHEMICAL SURVEY RESULTS

3.1 INTRODUCTION

As the initial investigation revealed the possibility of early (1950s and 1960s) disposal of chemical wastes at this site (conversations with John Hickman - former UCD employee, currently employed by the State of California, Department of Health Services, Radiologic Health Section in Sacramento, California), samples of subsurface soil were obtained for chemical analysis. These samples were obtained for us by the Anderson Geotechnical crew using the standard "California Core" technique. These samples were obtained at locations as shown in Figure 3.1.1. All samples were taken at a depth of twenty (20) feet.

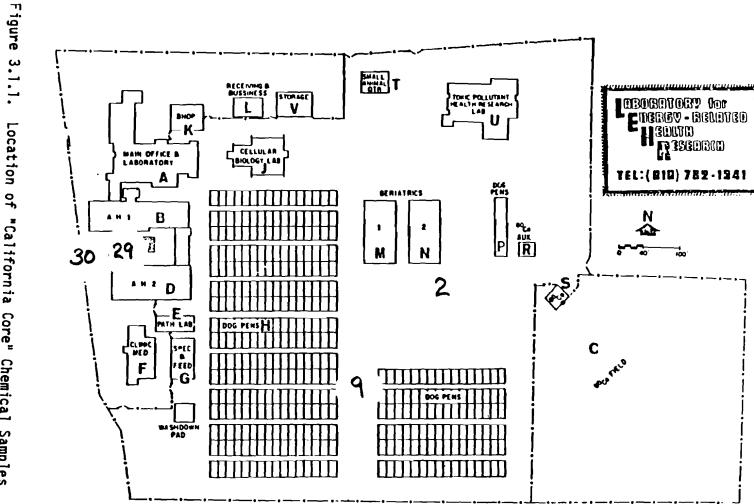
3.2 CHEMICAL ANALYSIS

These samples were submitted to Rockwell EMSC Laboratory for chemical analysis as specified in the DOE Scope of Work. The analytical team was headed by Dr. Colovos of EMSC. A copy of the complete report as received from EMSC appears in Appendix B.

3.3 CHEMICAL RESULTS

A portion of the report of the chemical analysis is reported in Figures 3.3.1 to 3.3.7. The complete report is reproduced in Appendix B.

According to Dr. Colovos of EMSC, no hazardous quantities of chemical contaminants were noted in the samples from the LEHR site.



"California Core" Chemical Samples

VOA Compounds in the Soil Samples

Compound	Concentration, ug/kg (wet weight)			
	<u>#137</u>	<u>#139</u>	#140	<u>#143</u>
methylene chloride		_	12	10

Figure 3.3.1. VOA Compounds in the Soil Samples

Compound	Concenti	ration, ug/	cg (wet wei	wet weight)		
	#137	<u>#139</u>	#140	<u>#143</u>		
bis(2-ethyl haxyl) phthalate	_		3300	2800		

Figure 3.3.2. Semivolitale Compounds in Soil Samples

		mg/kg in wet sample			
	#137	#1 <u>39</u>	# 140	#143	STLC
Sb	<0.2	<0.2	<0.2	<0.2	157
A.s	5.3	4.6	7.4	7.6	53
Ва	170	230	180	210	1050
Be	<2	<2	<2	<2	7.8
Cd	<2	<2	<2	<2	10.5
Cr (VI)				ł	53
Cr	51	53	27	53	5880
Co	16	24	33	15	840
Cu	41	35	20	40	263
F	23.4	31.3	30.2	72.6	1890
Pb	<13	<13	<13	<13	53
Нg	<0.5	<0.5	<0.5	<0.5	2.1
Мо	<500	<500	<500	<500	3675
N1	<100	102	<100	115	210
Se	<1	<1	<1	<1	10.5
Ag	<2	<2	<2	<2	52.5
Tl	<50	<50	<50	<50	73.5
٨	<200	<20 0	<200	<200	. 252
Zn	80.2	74.1	45.7	69.4	2625
vater	15.92	14.5%	5.9%	11.12	

Figure 3.3.3. Metals in Soil Samples

Hazardous Substance List (HSL)* and Contract Required Detection Limits (CEDL)**

			Det	Detection Limits		
			Low Water	Low Soil/Segiment		
	Volatiles	CAS Number	ug/L	ug/Kg		
1.	Chloromethane	74-87-3	10	10		
	Browne thene	74-83-9	10	70		
	Vinyl Chloride	75-01-4	10	10		
	Chloroethane	75-00-3	10	10		
	Mathylene Chloride	75 -09-2	5	5		
	Acetone	67-64-1	10	10		
7.	Carbon Disulfide	75-15-0	.5	5		
	1,1-Dichloroethene	75 - 35 -4	5	5		
	1,1-Dichloroethene	75-35-3	5	5		
10.	trans-1,2-Dichloroethene	15 6-60- 5	5	5		
	Chloroform	67 -66- 3	5	5		
	1,2-Dichloroethase	107 -06- 2	5	5		
	2-Butanone	78 -9 3-3	10	10		
	1,1,1-Trichloroethane	71-55 -6	5	5		
15.	Carbon Tetrachloride	56-23-5	5	5		
16.	Vinyl Acetate	108-05-4	10	10		
	Bromodichloromethane	75-27-4	5	5		
	1,1,2,2-Tetrachloroethane	79-34-5	5	5		
19.	1.2-Dichloropropana	7 8-67- 5	5	5		
20.	trans-i,3-Dichloropropene	10061-02-6	5	5		
21.	Trichloroethene	79-01-6	5	5		
22.	Dibrosochloromethene	124-48-1	5	5		
	1,1,2-Trichloroethane	79-00-5	5	5		
_	Benzene	71-43-2	5	5		
25.	cis-1,3-Dichloropropene	10061-01-5	5	5		

(continued)

Figure 3.3.4. Hazardous Substance List (HSL)* and Contract Required Detection Limits (CRDL)**

			Detection Limits		
	Volatiles	CAS Number	Low Water	Low Soil/Sediment ⁵ ug/Kg	
26.	2-Chloroethyl Vinyl Ether	110-75-8	10	10	
	Broneform	75-25-2	5	5	
28.	2-Hexanone	591-78-6	10	ro	
29.	4-Me thyl-2-pentagone	108-10-1	10	10	
30.	Tetrachloroethene	127-18-4	5	5	
31.	Toluene	108-88-3	5	\$	
32.	Chlorobenzene	108 -9 0-7	5	5	
33.	Ethyl Benzene	100-41-4	5	5	
34.	Styrene	100-42-5	5	5	
35.	Total Tylenes		5	5	

^{*}Medium Water Contract Required Detection Limits (CRDL) for Volatile HSL Compounds are 100 times the individual Low Water CRDL.

Figure 3.3.4 (Continued)

Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Volatile ESL Compounds are 100 times the individual Low Soil/Sediment CRDL.

			Detection Limits		
			Low Water	Low Soil/Sediment	
	Semi-Volatiles	CAS Number	ug/ L	ug/Kg	
36.	N-Nitrosodimethylamine	62-75-9	10	330	
	Phenol	108-95-2	10	330	
•	Aniline	62-53-3	10	330	
	bis(2-Chloroethyl) ether	111-44-4	10	330	
	2-Chlorophenol	95-57-8	10	330	
41.	1.3-Dichlorobensene	541-73-1	10	330	
	1.4-Dichlorobensens	106-46-7	10	330	
	Bensyl Alcohol	100-51-6	10	330	
	1.2-Dichlorobensene	95-50-1	10	330	
	2-He thylphenol	95-48-7	10	330	
46.	bis(2-Chloroisopropyl)				
	ether	3 9638-32-9	10	330	
47.	4-Methylphenol	106-44-5	10	330	
	M-Hitroso-Gipropylamine	621-64-7	10	330	
49.	Herschloroethane	67-72-1	10	330	
50.	Ni trobensene	98 -9 5-3	10	330	
51.	Isophorone	78 -59- 1	10	330	
52.	2-Mitrophenol	88-75-5	10	330	
53.	2,4-Dimethylphenol	105 -6 7 -9	10	330	
54.	Benzoic Acid	65-85-0	50	1500	
55.	bis(2-Chloroethoxy)				
	methane	111 -9 1-1	10	330	
56	2,4-Dichlorophesol	120-83-2	10	330	
57.	1,2,4-Trichlorobensene	120-62-1	10	330	
58.	Naphthalene	91-20-3	10	330	
59.	4-Chlorosniline	106-47-8	10	330	
60.	Hexachlorobutadiene	87 -68- 3	10	330	
61.	4-Chloro-3-methylphenol				
	(para-chloro-mata-crasol		10	330	
	2-Methylmaphthalene	91-57 -6	10	330	
	Hexachlorocyclopentadiane		10	330	
	2,4,6-Trichlorophenol	8 8- 06-2	10	330	
65.	2,4,5-Trichlorophesol	9 5-95-4	50	1600	

(continued)

Figure 3.3.4 (Continued)

			Detection Limits			
			LOW HELET	Low Soil/Sediment		
	Semi-Volatiles	CAS Number	ug/L	ug/Kg		
66.	2-Chloronaphthalene	91-58-7	10	330		
	2-Nitrospiline	88-74-4	50	1600		
-	Dimethyl Phthalate	131-11-3	10	330		
	Acenaphthylene	208-96-8	10	330		
	3-Mitroaniline	99-09-2	50	1600		
71.	Acenaphthene	83-32- 9	10	330		
	2,4-Dinitrophenol	51-28-5	50	1600		
	4-Nitrophenol	100-02-7	50	1600		
	Dibensofuran	132-64-9	10	330		
	2,4-Dinitrotoluene	121-14-2	10	330		
76.	2.6-Dimitrotoluene	606-20-2	10	330		
77.	Diethylphthalate	84-66-2	10	330		
	4-Chlorophenyl Phenyl					
	echer	7005-72-3	10	330		
79.	Fluorene	86-73-7	10	330		
80.	4-Mitroeniline	100-01-6	50	1600·		
81.	4,6-Dinitro-2-methylphenol	534-52-1	50	1600		
82.	N-mitrosodiphenylamine	8 6- 30 -6	10	330		
83.	4-Bromophenyl Phenyl ether	101-55-3	10	330		
84.	Hexachlorobensene	118-74-1	10	330		
85.	Pentachlorophenol	87 -86- 5	50	1600		
86.	Phenanthrene	85-01-8	10	330		
87.	Anthracene	120-12-7	10	330		
88.	Di-o-butylphthalate	84-74-2	10	330		
89.	Fluoranthene	206-44-0	10	330		
90.	Benzidine	92-87-5	50	1600		
91.	Pyrene	129-00-0	10	330		
92.	Butyl Bensyl Phthalats	8 5-68- 7	10	330		
93.	3,3'-Dichlorobenzidine	91 -9 4-1	20	660		
94.	Benzo(a)anthracene	56-55-3	10	330		
95.	bis(2-ethylhamyl)phthalate	117-61-7	10	330		
96.	Chrysene	218-01-9	10	330		
97.	Di-m-octyl Phthalate	117-64-0	10	330		
98.	Benzo(b)fluoranthene	205-99-2	10	330		
99.	Benzo(k)fluoranthene	207-08-9	10	330		
100	lenso(a)pyrene	50-32-8	10	330		

(continued)

Figure 3.3.4 (Continued)

		Detection Limits		
		Low Water	Low Soil/Sediment	
Pesticides	CAS Number	ug/L	ug/Kg*	
104. alpha-BHC	319-84 -6	0.05	2.0	
105. beta-BRC	319-85-7	0.05	2.0	
106. delta-BHC	319-86-8	0.05	2.0	
107. gamma-BHC (Lindane)	58-8 9- 9	0.05	2.0	
108. Reptachlor	76-44-8	0.05	2.0	
109. Aldrin	309-00-2	0.05	2.0	
110. Reptachlor Epoxide	1024-57-3	0.05	2.0	
111. Endosulfan I	95 9- 98-8	0.05	2.0	
112. Dieldrin	60-57-1	0.10	4.0	
113. 4,4'-DDE	72-55-9	0.10	4.0	
114. Endrin	72-20-8	0.10	4.0	
115. Endosulfan II	3 3213-65-9	0.10	4.0	
116. 4,4'-DDD	72-54-8	0.10	4.0	
117. Endris Aldehyde	7421 -9 3 -4	0 10	4.0	
118. Endosulfan Sulfate	1031-07-8	0.10	4.0	
119. 4,4'-DDT	50-29-3	0.10	4.0	
120. Endrin Recone	53494-70-5	0.10	4.0	
121. Methoxychlor	72-43-5	0.5	20.0	
122. Chlordane	57-74 -9	0.5	20.0	
123. Toxaphene	8001-35-2	1.0	40.0	
124. AROCLOR-1016	12674-11-2	0.5	20.0	
125. AROGLOR-1221	11104-28-2	0.5	20.0	
126. AROCLOR-1232	11141-16-5	0.5	20.0	
127. AROCLOR-1242	5346 9- 21-9	0.5	20.0	
128. AROCLOR-1248	12672-29 -6	0.5	20.0	
129. AROCLOR-1254	1'.097 -69- 1	1.0	40.0	
130. AROCLOR-1260	11096-82-5	1.0	40.0	

^{*}Medium Water Contract Required Detection Limits (CRDL) for Pesticide HSL Compounds are 100 times the individual Low Water CRDL.

Figure 3.3.4 (Continued)

^{*}Medium Soil/Sediment Contract Required Detection Limits (CEDL) for Pesticide HSL compounds are 60 times the individual Low Soil/Sediment CEDL.

^{*} Wherever the term "priority pollutant(s)" is used in this contract and in any references cited in this contract, it is intended to mean "Hazardous Substances List (RSL) Compound(s)," which include all compounds listed in this Exhibit.

^{**} Specific detection limits are highly matrix dependent. The detection limits listed herein are provided for guidance and may not always be achievable.

		Detection_Limits			
		Low Water	Low Soil/Sediment		
Semi-Volatiles	CAS Number	ug/L	ug/Kg		
101. Indeno(1,2,3-cd)pyrene	193-39-5	10	330		
102. Dibenz(a,h)anthracene	53-70-3	10	330		
103. Benzo(g,h,i)perylene	191-24-2	10	330		

CMedium Water Contract Required Detection Limits (CRDL) for Semi-Volatile HSL Compounds are 100 times the individual Low Water CRDL.

Figure 3.3.4 (Continued)

desdium Soil/Sediment Contract Required Detection Limits (CRDL) for Semi-Volatile HSL Compounds are 60 times the individual Low Soil/Sediment CRDL.

VOA Percent Surrogate Recovery

Surrogate Compounds		Percen	t Recover	7	
(Approved recovery range)	#137	#139	#140	#143	Method Blank
SURR-1 (1,2-dichloroethane-d ₄)	95	91	96	93	98
SURR-2 (benzene d ₆)	115	118	126	128	118
SURR-3 (toluene d ₈)	129	93	96	98	104
SURR-4 (p-bromofluorobenzene)	132	91	95	92	108

Figure 3.3.5. VOA Percent Surrogate Recovery

BNA Percent Surrogate Recovery

Surrogata Compounds	Percent Recovery				
(Approved recovery range)	#137	# 139	# 140	#143	Method Blank
SURR-1 (2-fluorophenol)	114	89	56	63	56
SURR-1 (phenol-d ₅)	77	65	40	50	41
SURR-3 (nitrobenzene-d ₅	77	56	48	58	51
SURR-4 (2-fluorobiphenyl)	68	61	57	66	58
SURR-5 (2,4,6-tribromophenol)	93	96	32	44	30
SURR-6 (terphenyl-d ₁₄)	72	77	32	33	30

Figure 3.3.6. BNA Percent Surrogate Recovery

Pesticide Surrogate Recovery

Surrogata Compounds	I	Percent	Recover		
(Approved recovery range)	#137	#139	#140	#143	Method Blank
Dibutyl chlorendate	87	83	93	84	90

Figure 3.3.7. Pesticide Surrogate Recovery

4.0 RADIOLOGICAL SURVEY RESULTS

4.1 INTRODUCTION

A radiological survey was carried out on this site as described in Document NOOISRRI300I3, "Proposed Survey Plan." Details of the radiological survey methods can be found in Appendix D of this report.

4.2 SURFACE FEATURES SURVEY

4.2.1 General Surfaces Survey

A qualitative gross alpha, gross beta, and gross gamma survey of the facility was carried out immediately upon our arrival upon the LEHR site. No contamination or unexpected gamma fields were encountered. All contamination on accessible surfaces was at background levels. Measurable gamma fields were noted near the Co-60 irradiation field, the IMHOFF waste treatment facility, and the AH-1 outside refrigerated storage at levels similar to those noted by LEHR and DOE/SAN staff.

4.2.2 Statistical Surfaces Survey

A statistical gross alpha and gross beta survey was conducted on flat surfaces as available. Please refer to Figure 4.2.2.1 for locations of the survey points. These survey points were located in a random-biased fashion such that, based upon the judgment of the surveyors and information related to them by LEHR staff, the most likely contaminated areas were given the heaviest coverage. Figures 4.2.2.2 and 4.2.2.3 are graphic plots of the statistical distribution of the data.

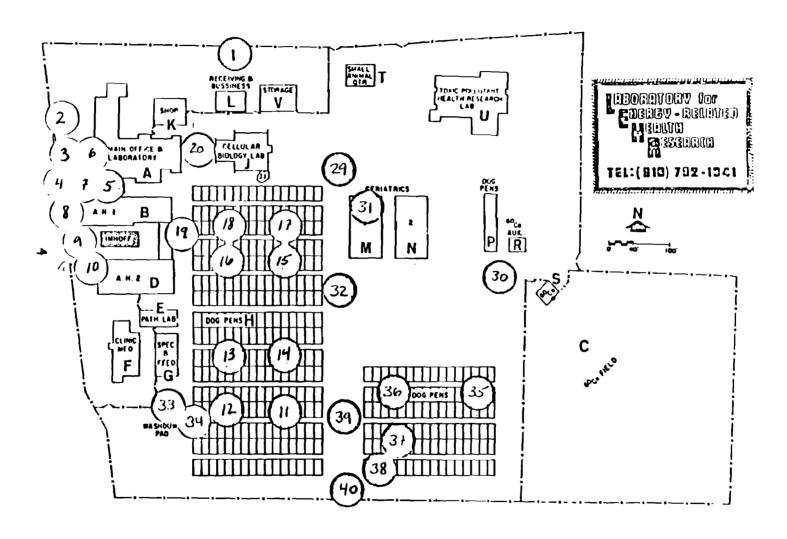


Figure 4.2.2.1. Statistical Surface Survey Point Locations

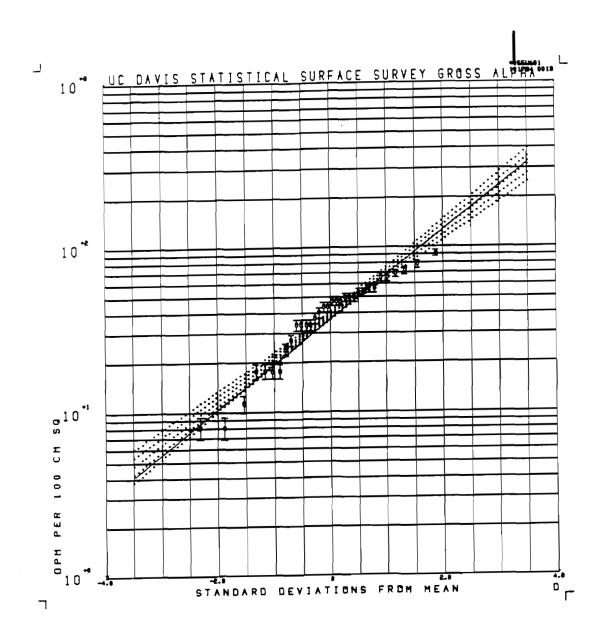


Figure 4.2.2.2. Statistical Surface Survey Gross Alpha Data Plot

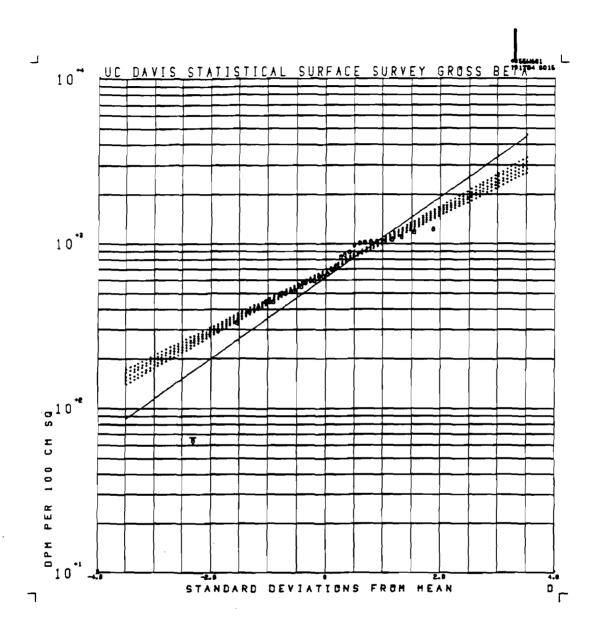


Figure 4.2.2.3. Statistical Surface Survey Gross Beta Data Plot

The slight spread in the data is representative of the varied surfaces surveyed and not indicative of measurable levels of contamination traceable to LEHR activities. While this initial assessment survey was not of sufficient rigor to determine if the facility would meet release criteria, the distribution of the data is such that these surfaces appear essentially free of radioactive contamination.

4.2.3 HVAC System Survey

A radiologic survey was conducted of the HVAC system outlets associated with the AH-1 and AH-2 buildings of the LEHR compound. Please refer to Figure 4.2.3.1 for locations of these samples. Smear samples and survey (alpha and beta) meter readings were taken from the outlets past the HEPA - (not labeled) filters in the cases where this was possible. Most of the stack outlets were covered with a wire mesh which precluded any of our normal survey techniques. No elevated readings were discovered with survey meters, but one smear showed elevated beta activity. The results were reported in Figures 4.2.3.2 and 4.2.3.3. Insufficient activity was found for gamma spectroscope analysis.

4.2.4 Surface Soil Survey

Soil samples were obtained from various locations in the LEHR facility as shown in Figure 4.2.4.1. These samples were taken in locations which were representative of the general area and have a good likelihood, in the opinion of the surveyor, to retain radioactive material. These samples were screened for both gross alpha and gross beta. No indication was found of any contamination attributable to the LEHR operations. A graphic representation of these data is given in Figures 4.2.4.2 and 4.2.4.3.

4.2.5 Field Drain Survey

The proposed survey plan called for an investigation of possible contamination in the field or storm drain system which services the out-of-doors

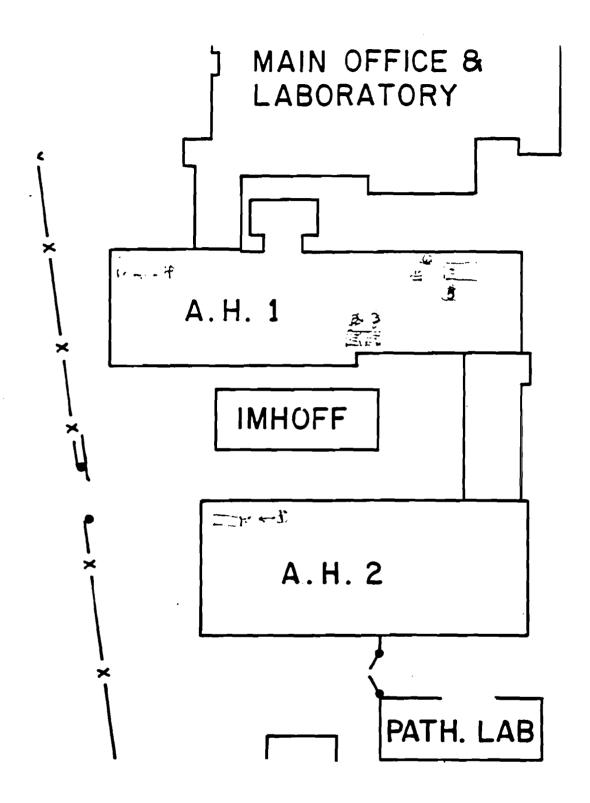


Figure 4.2.3.1. HVAC System Survey Sample Locations

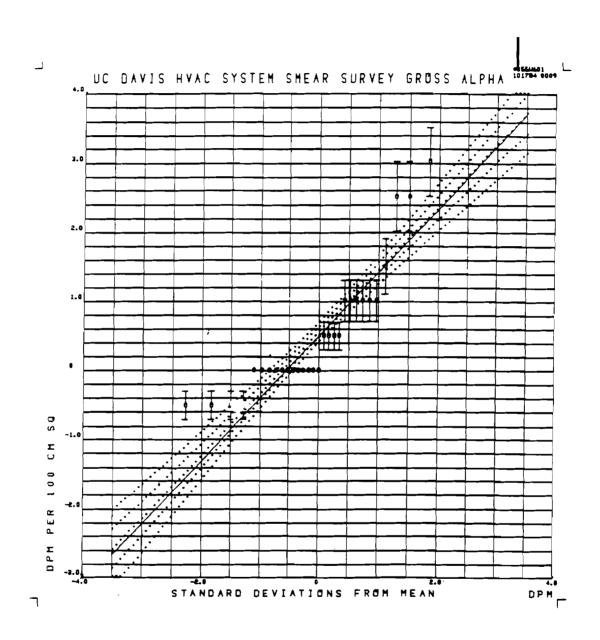


Figure 4.2.3.2. HVAC System Survey Alpha Smear Plot

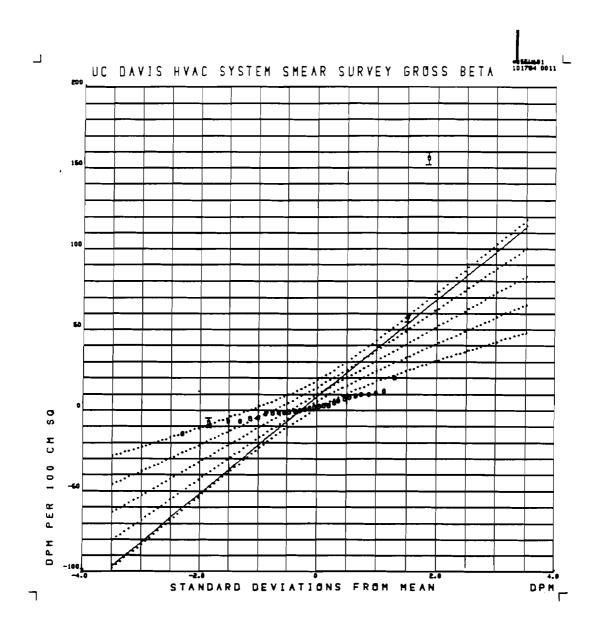


Figure 4.2.3.3. HVAC System Survey Beta Smear Data Plot

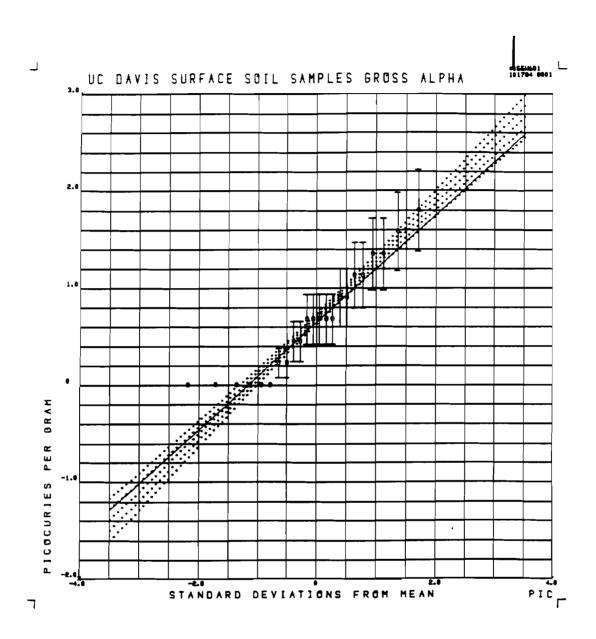


Figure 4.2.4.2. Surface Soil Survey Gross Alpha Data Plot

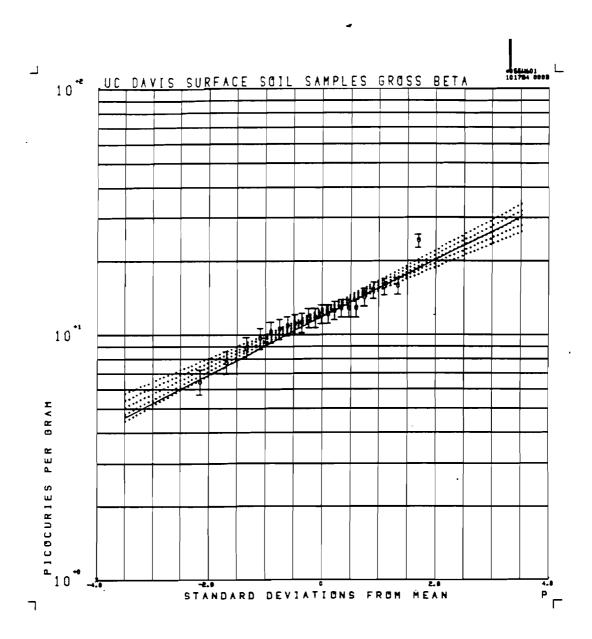


Figure 4.2.4.3. Surface Soil Survey Gross Beta Data Plot

areas around the dog pens. This effort had to be abandoned due to both a Tack of access and an unsuitable environment. The drain covers had been paved over in the past, and several hours were expended in an unsuccessful attempt to open one of them. A visual inspection revealed running water in most of these drains and a lack of sediment. It is conjectured that the water came from the sprinkler system over the dog pens, which is controlled by a thermostat; when the ambient air temperature reaches 95°F, a sprinkler system is turned on to provide cooling to the dogs in the outdoor pens. It was our opinion that any contamination that might have entered the system would have been long since been flushed away. A sediment sample was obtained at the outlet of this system and measured for gross alpha and gross beta activity. The sediment was of a rocky sand nature and would not be expected to have absorptive qualities. Sediment samples were also obtained downstream from the discharge point of this system to Putah Creek. These samples also showed no activity above normal background levels. In short, the results showed no contamination. Please refer to Figure 4.2.5.1 for locations of samples.

4.2.6 Dog Pens

The dog pen areas initially appeared to be an area of great interest, but information uncovered in conversation with Dr. M. Goldman led us to understand that the dogs were kept indoors in cages during the ingestion cycle of the experiment and were held for 30 additional days until the mobile activity in their systems was eliminated. Because of this, the amount of activity which could have been deposited was much less than expected. Dr. Goldman related that the LEHR staff had calculated the highest possible value of approximately 200 microcuries per pen for the animal with the highest activity. With water from rainfall and the dog cooling system, most of this activity would have migrated from the near surface region of the soil by this time. Measurements made on samples from this area tend to support this conclusion.

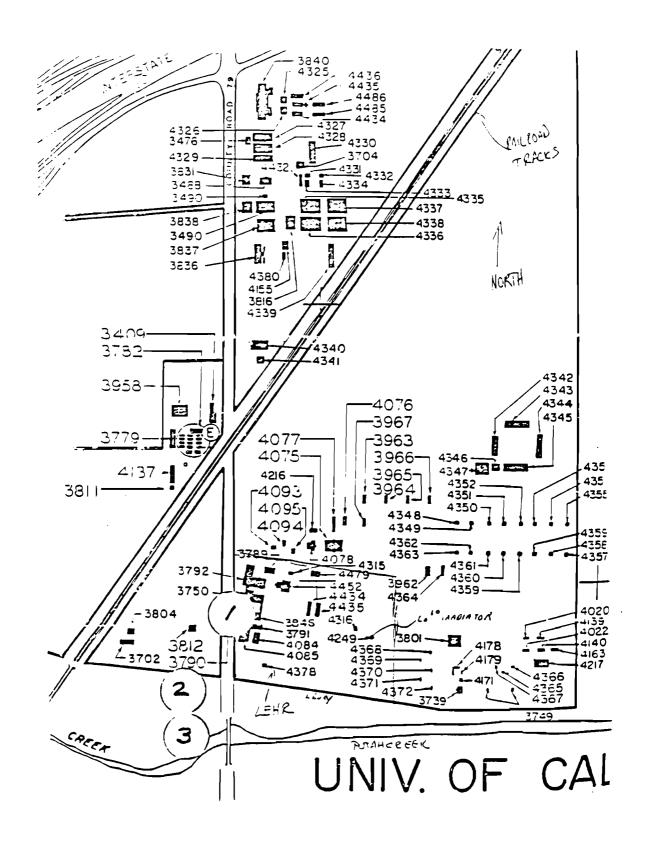


Figure 4.2.5.1. Field Drain Sample Locations

Measurements of gross alpha and gross beta, as well as near surface (clay under 8-12 in. of crushed limestone in dog pens) samples were obtained. These data are included in the statistical survey and near surface soil survey sections; no measurable contamination was found.

4.3 SUBSURFACE SOIL STUDIES

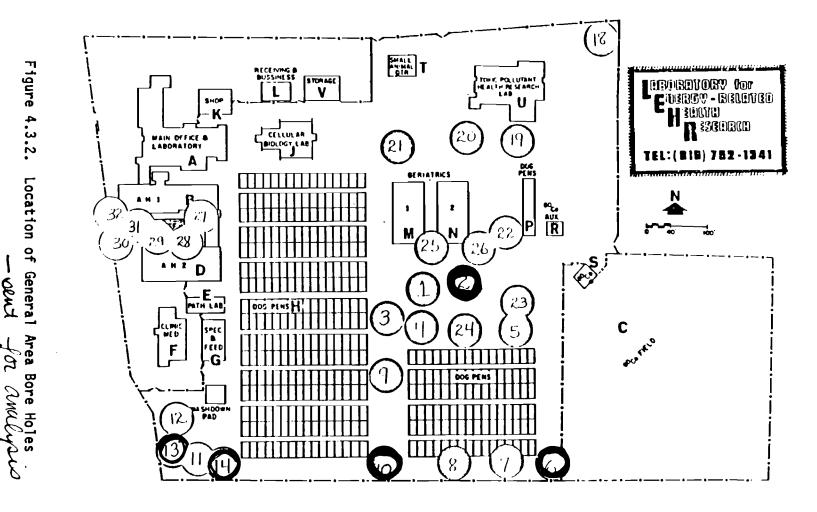
As the planning progressed, the primary area of concern was thought to be possible waste burial sites. A contract was let to Anderson Geotechnical of Roseville, California, to obtain subsurface soil and debris samples. The equipment employed was a truck-mounted drilling rig with an 8-in. hollow core auger. The equipment available was capable of 20-ft-deep holes.

Little information on the location, number, depth, or contents of the burial sites was known at the time of the planning effort. Figure 4.3.1 shows the anticipated subsurface features based on this verbal information.

Based upon this information, the survey plan called for sample holes to be dug near the locations shown in Figure 4.3.2. Figure 4.3.2 shows the actual location of the holes drilled; in some cases, the drilling equipment could not access the areas planned.

All of the water, sewage, electric, telephone, and compressed air lines were buried, and there was little information available concerning the location of these underground utilities. In three cases, the holes planned were in an area of many lines, and no information as to their exact location and no substitute locations to examine that feature was found. As such, these three holes were not bored.

Due to the uncertain information available as to the depth of the buried features, a mix of 5- and 20-ft-deep holes were bored. The depths and numbers of holes were based upon both our early information and budgetary constraints. A total of twenty-nine (29) holes were bored with eighteen 5-ft-deep, ten 20-ft-deep (see Figure 4.3.1), and one 10-ft-deep hole.



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Based on acquired information future holes should be no less than ten feet deep.

One of the Rockwell survey team members was present at the boring operation to watch for sudden changes in soil consistency and debris as well as to monitor for radioactive contamination. No contamination was measurable with the hand-held survey instruments used. Soil samples were obtained from the soil at the depth of approximately 6 in., and at 5-ft increments thereafter. These soil samples were screened for gross alpha, gross beta, and analyzed by gamma spectroscopy.

The sample holes were filled by the LEHR staff after our departure.

4.3.1 Burial Grounds and General Area Survey

The results of the gross alpha and gross beta are presented graphically in Figures 4.3.1.1 and 4.3.1.2. No significant departure from background was observed in this screening of the soil samples. This method of analysis has a sensitivity of approximately 50 picocuries (pCi) per gram of soil.

Each sample hole was scanned for gross beta and gross gamma activity. Due to the fragile nature of alpha radiation detection probes, and the short range of alpha in air, no attempt was made to scan for gross alpha. A 1-min. gross gamma count was taken as follows: 3 ft above the center of each hole (POPULATION 1), in the center of the hole with the crystal just below the surface of the undisturbed soil (POPULATION 2), at a depth of 5 ft (POPULATION 3), at a depth of 10 ft (POPULATION 4), at a depth of 15 ft (POPULATION 5), at a depth of 20 ft (POPULATION 6). The breakdown of the data into populations was to enable an easy viewing of the graphic plot of the data.

The gamma scanning procedure located gamma activity in two locations. This data is presented in Figure 4.3.1.3. Data from the 1-min. counts is presented by population in Figures 4.3.1.4 through 4.3.1.9. The combined data is

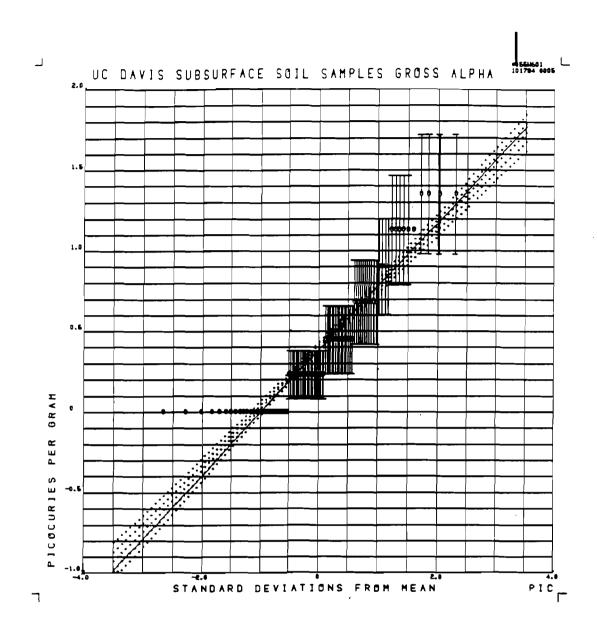


Figure 4.3.1.1. Subsurface Soil Survey Gross Alpha Data Plot

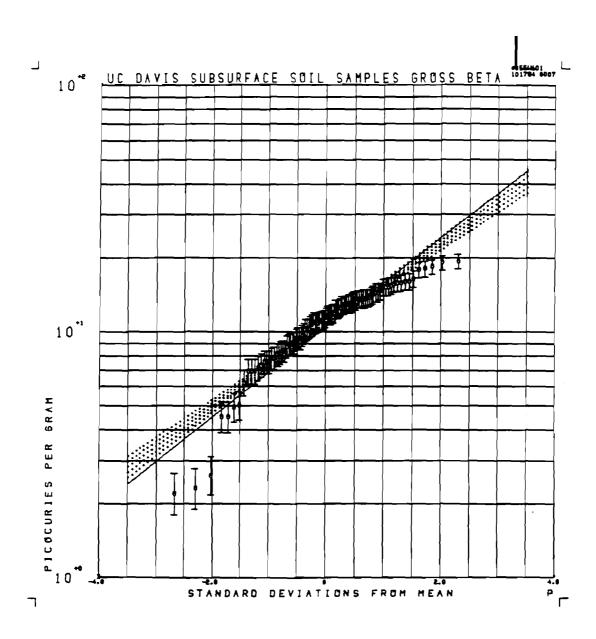


Figure 4.3.1.2. Subsurface Soil Survey Gross Beta Data Plot

presented in Figure 4.3.1.10. No indication of increased pure beta activity was found in any of the bore holes.

No change Y β No 10-14K 12 20 No 10-14K 13 20 Yes 60K cpm 10 ft West 14 5 Yes 60K cpm 3 5 ft Moreover 3 5 ft Moreov	Hole No.	Depth (ft)	Elevated Reading (Y or N)	Maximum Reading	Depth of Maximum Reading
15	1 2 3 4 5 6 7 8 9 10 11 2 13 14 15 16 17 18 19 20 22 23 24 25 26 27 28 29 30 31	(ft) 5 5 5 20 20 20 20 20 5 5 5 5 20 20 20 20 20 20 20 20 20 20 20 20 20	No change Y B	60K cpm 40K cpm TAKEN	10 ft 200 to 3.5 ft pics

Figure 4.3.1.3. Bore Hole Survey Gross Gamma Scan Data

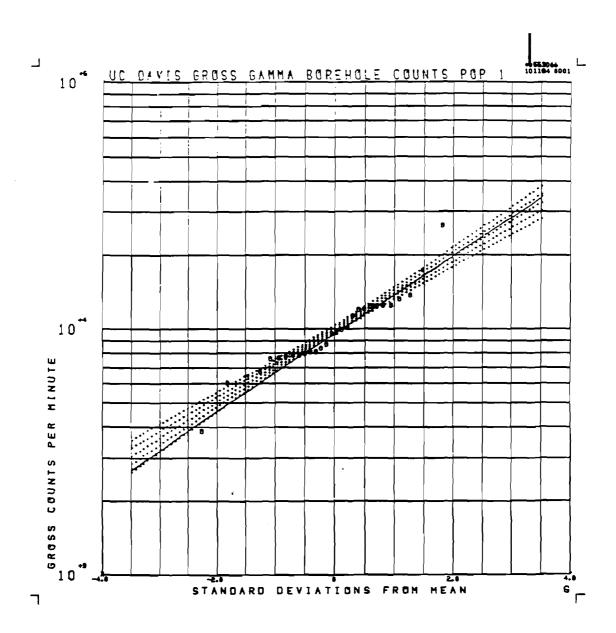


Figure 4.3.1.4. Bore Hole Survey Gross Gamma Count Data (POPULATION 1)

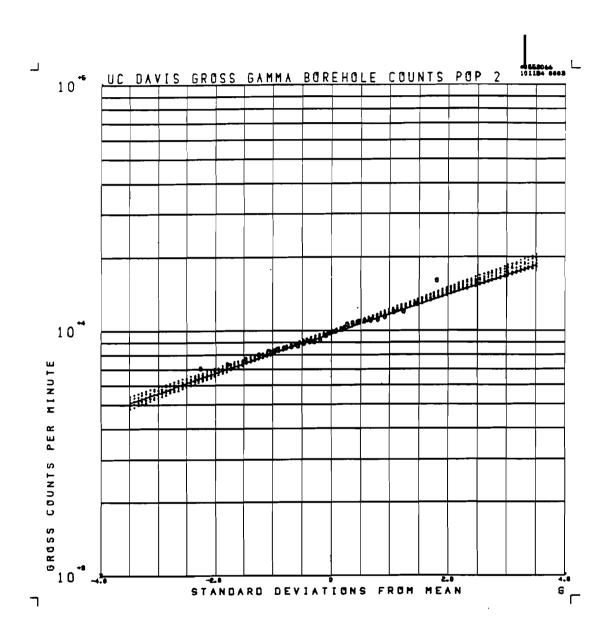


Figure 4.3.1.5. Bore Hole Survey Gross Gamma Count Data (POPULATION 2)

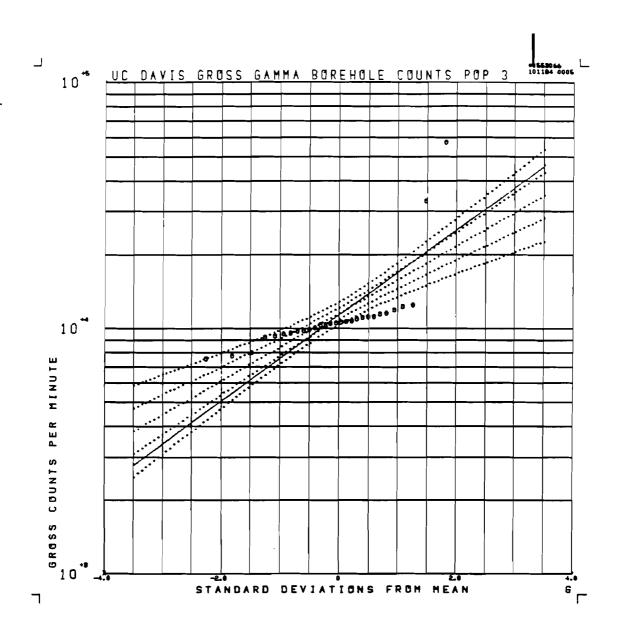


Figure 4.3.1.6. Bore Hole Survey Gross Gamma Count Data (POPULATION 3)

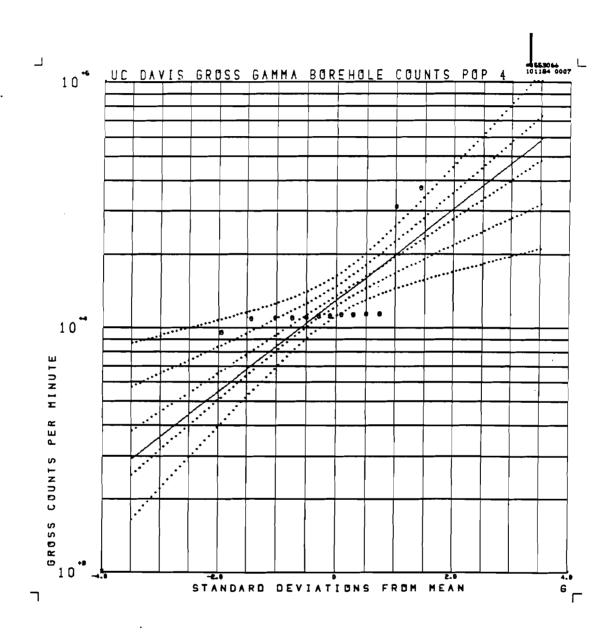


Figure 4.3.1.7. Bore Hole Survey Gross Gamma Count Data (POPULATION 4)

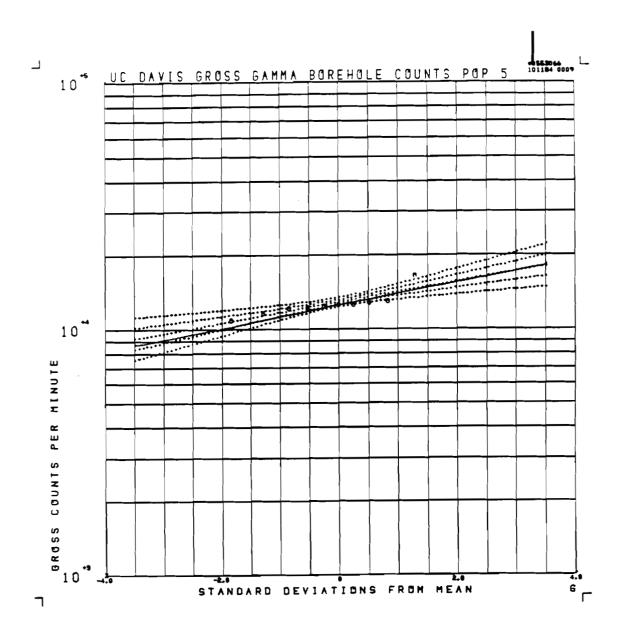


Figure 4.3.1.8. Bore Hole Survey Gross Gamma Count Data (POPULATION 5)

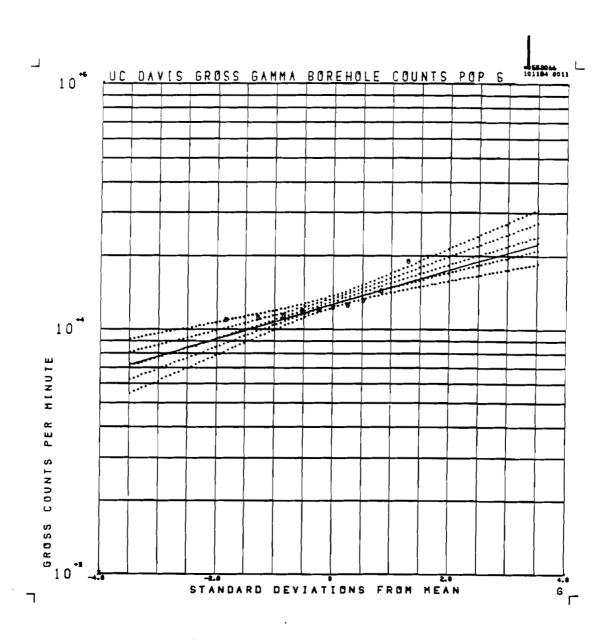


Figure 4.3.1.9. Bore Hole Survey Gross Gamma Count Data (POPULATION 6)

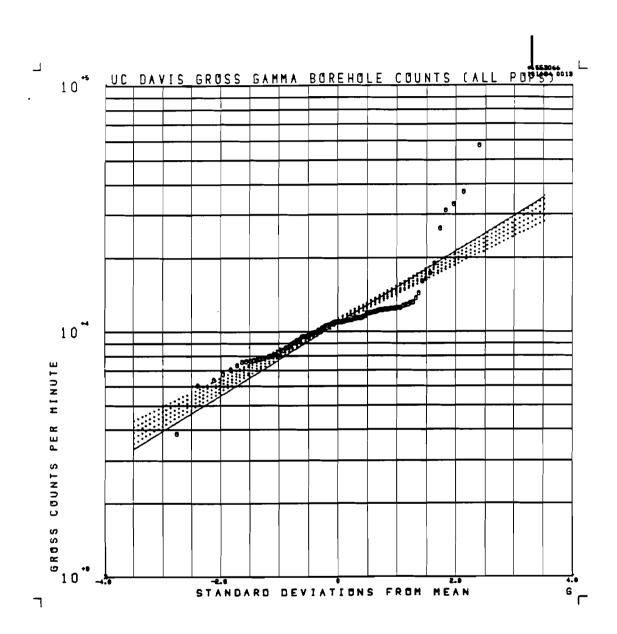


Figure 4.3.1.10. Bore Hole Survey Gross Gamma Count Data (ALL POPULATIONS)

As can be seen from Figure 4.3.1.3, a sharply increased level of gamma activity can be found in bore holes 13 and 14. Both of these locations are shown in detail in Figure 4.3.1.13.

Gamma spectroscopy was able to determine that there was some amount of Cs-137 activity in hole 14 and probably some other gamma-emitting radio-nuclides. Exact determinations of the quantities involved are impossible due to the unknown geometry and amount of shielding. Further excavation is required. A contribution to the low-energy portion of the spectra by the scattered radiation (sky shine) from the Co-60 irradiation field contributed greatly to the uncertainty. Due to lack of time and a desire to prevent possible spread of contamination, no attempt was made to uncover the source of activity. A printout of the spectral analysis is reproduced in Figure 4.3.1.11.

The activity in hole 13 was much more difficult to characterize by gamma spectroscopy due to the increased depth and the physical size of the HPGe detector system (see Figure 4.3.1.11).

4.3.2 Leach Fields

The early information which we received was incomplete and inaccurate. Figure 4.3.2.1 shows the location of the fields as best we knew at the start of the project. Figure 4.3.2.2a shows our best information at the end of the survey effort. We have been unable to confirm either the exact locations, configurations, or construction details of any of these features. Some of the leach fields may have been used to dispose of nonradioactive waste, but this initial assessment effort was not able to locate such information if it exists in written form. Verbal communications with LEHR staff indicate such data may not exist.

UC DAVIS SIDE B OF CANBERRA TAPE AS SEEN ON ENERGY COMPENSATED SERIS 85

TAG NO. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ADCN | LIVE TIME = 1000 TRUE TIME = 1002 17 OCT 84 13:57
COLLECTED AT: 13:20:52.7 17 OCT 84

ROIM 1 FROM 231.8 KEV TO 244.7 KEV
PEAK AT 242.6 KEV FUHM= 1.7 KEV
INTEGRAL= 3111 RATE= 3.1 CPS
AREA= 507 ERR= 25.2%

PB-214 AT 241.9 KEV = 0.14546E25 UCI

ROIM 2 FROM 576.1 KEV TO 591.0 KEV
PEAK AT 585.3 KEV FUMM= 2.9 KEV
INTEGRAL= 568 RATE= 0.5 CPS
AREA= 289 ERR= 15.2%

HR 89 - AT - 505.8 HEV - - 0.24474E-32-UCI

ROIN 3 FROM 601.0 KEV TO 615.7 KEV
PEAK AT 606.6 KEV FUHM= 2.3 KEV
INTEGRAL= 577 RATE= 0.5 CPS
AREA= 267 ERR= 17.2%

ROIM 4 FROM 654.3 KEV TO 667.3 KEV
PEAK AT 659.3 KEV FUHH= 3.9 KEV
INTEGRAL= 712 RATE= 0.7 CPS
AREA= 433 ERR= 10.6%
C5-137 @ 661.6 MeV
RB-09 AT 657.7 KEV = 0.10076E13 UGI
AG=110M AT 657.7 KEV = 0.17348E-03 UGI

ROIM 5 FROM 1165.2 KEV TO 1181.2 KEV
PEAK AT 1178.0 KEV FWHH= 5.1 KEV
INTEGRAL= 222 RATE= 0.2 CPS
AREA= 90 ERR= 33.3%

ROIN 6 FROM 1324.7 KEV TO 1341.2 KEV
PEAK AT 1331.7 KEV FWHM= 0.6 KEV
INTEGRAL= 105 RATE= 0.1 CPS
AREA= 3 ERR= >>>>X

CO-40 AT 1332-5 KEV - 4-26349E-04-UCI

ROIM 7 FROM 1451.2 KEV TO 1468.2 KEV
PEAK AT 1460.3 KEV FUHH= 7.9 KEV
INTEGRAL= 940 RATE= 0.9 CPS
AREA= 906 ERR= 3.62

K-40 AT 1460.8 KEV = ++59439E-01-UCI

Figure 4.3.1.11. Bore Hole 14 Gamma Spectrum

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Spectra too degraded due to depth of activity for analysis

Figure 4.3.1.12. Bore Hole 13 Gamma Spectrum

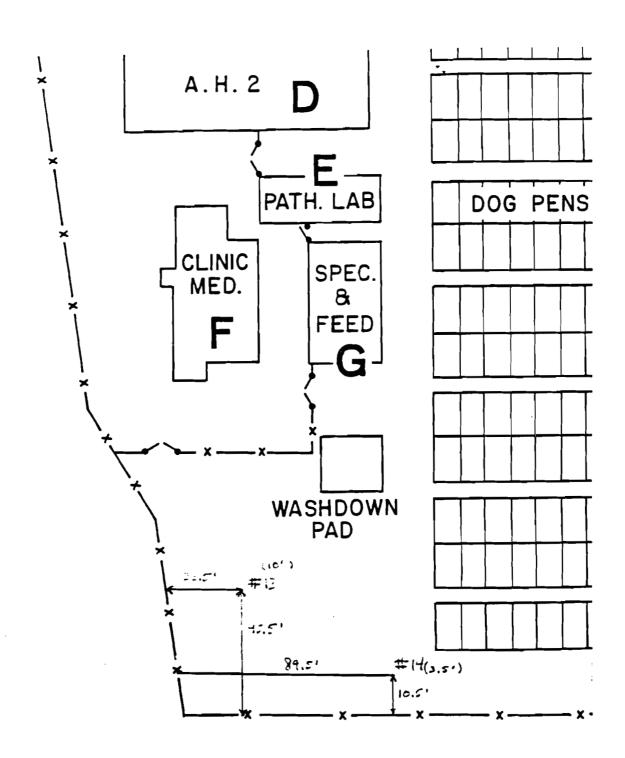


Figure 4.3.1.13. Detailed Plot of Location of Hole 13 and Hole 14

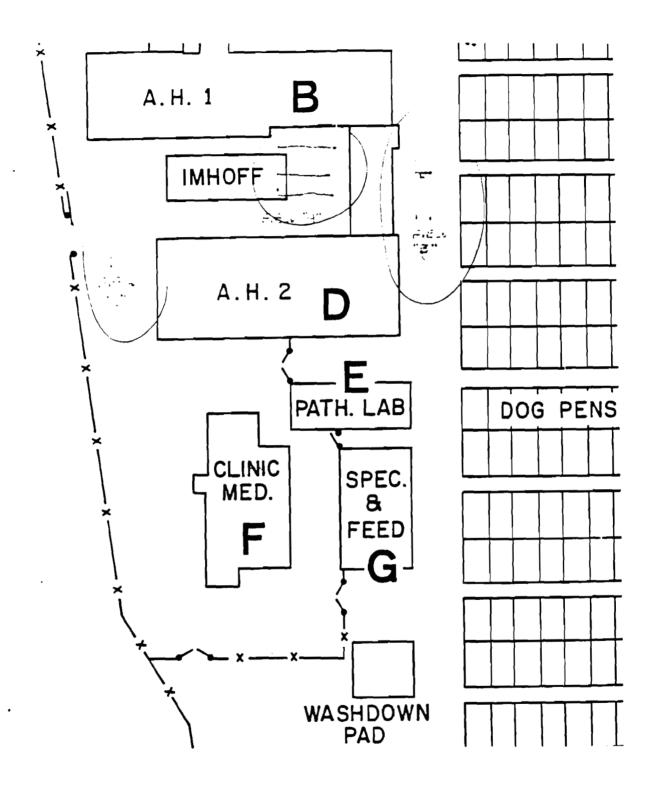


Figure 4.3.2.1. Leach Field Survey Early Data

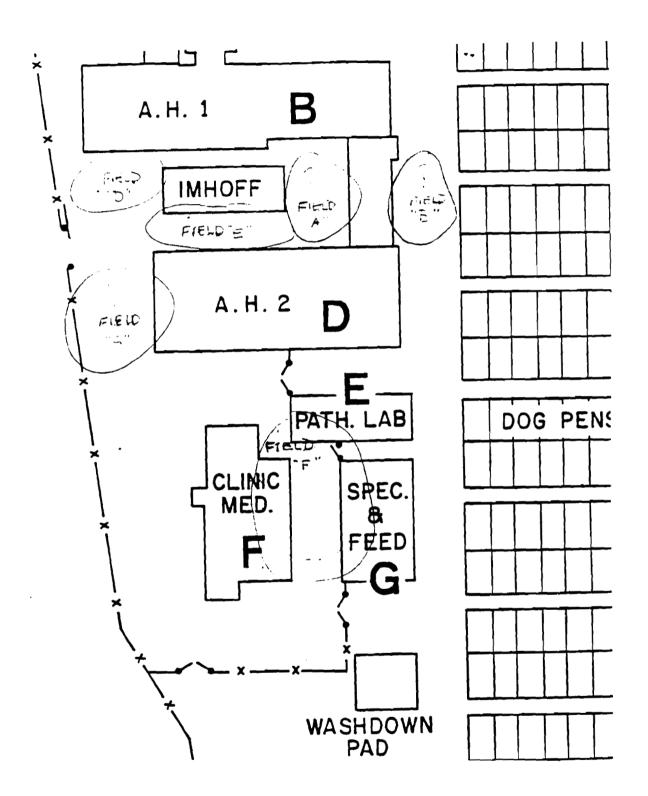


Figure 4.3.2.2.a. Leach Field Survey Updated Data

Some prints we were able to obtain were not identified as "proposed," "as planned," or "as built." Verbal information did not agree with these drawings. We were not able to either confirm or deny the existence of any of the leach fields.

Figure 4.3.2.3 shows details of the Ra-226 injection wells which points to either an unknown feature or a leach field. As this detail was not discovered until after the departure of the hole-boring crew, no samples were taken near this location. Field (1) is the field most LEHR staff remember, although there is some question as to its shape and exact location. Field (2) was identified to us by Mr. Holdstock of EH&S, but was marked on no drawings. Field (3) was marked on one copy of a blueprint by a bold pencil stroke with no explanation, but the detail in Figure 4.3.2.3 would tend to confirm its existence. Their existence was remembered by the LEHR staff questioned but could not be confirmed in our survey due to either buried pipelines in the area in one case (eastern field) or a building now over the area (southern field).

4.3.3 Radium Injection Wells

The exact construction details of these injection wells were not obtained. There seems to be a lack of information as to the quantity of radioactive materials which were injected into this system.

There is a 4-in. line feeding a distribution box for three injection wells. More beta activity was noted in this structure than in any of the three injection well structures. Three lines left the distribution box in the direction of the three injection wells. The south well had an additional 3-in. line going south (see Figure 4.3.2.3). The wells are spaced approximately 20 ft apart and are covered by a concrete "manhole" like structure. The depth of the wells is not known for certain. One staff member stated that they were 120 ft deep, and another related that they were 30 ft deep. The latter seems more reasonable as we discovered (from Mr. Bill Eaton of Eaton

, — FOUND EXTENSIVE BOX

w. 51

UNKNOWN INLET OR DITLET

WHICH IER

Figure 4.3.2.3. Top View of South Ra-226 Injection Well Detail

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Well Drilling, Woodland, California) that the university draws irrigation water from an aquifer approximately 90 ft deep, and that 20- to 50-ft-deep leach pits were common for sewage disposal in the area during the late 1950-1960 period. The wells are said to be filled with 4- to 8-in. cobbles. Because of the outdoor setting, an overlying mat of partially decomposed dog hair, and the desire not to spread contamination, this was not verified. Entry to the well pits proper was not attempted due to both a lack of special ladders and special safety equipment, and because there was a certain knowledge that contamination was present.

Please refer to Figure 4.3.3.1 for the layout and location of the radium injection well system. Please refer to Figure 4.3.3.2 for details of the near-surface portion of the radium injection well system.

Contamination was measured on the underside of the manhole covers as noted in Table 4.3.3.1.

TABLE 4.3.3.1

MANHOLE COVERS - DIRECT READINGS

(dpm/100 cm²)

Cover	Alpha	Gamma
North	3,000	1,250
Middle	20,000	12,500
South	1,000	BKG

No measurement of smearable contamination was made due to the heavily rusted condition of the manhole cover surfaces, but in the course of handling these manhole covers, it was discovered that the contamination was indeed transferrable.

The cause of this contamination is not known, but as the walls of the pits were contaminated, it is conjectured that the pits have experienced high water (contaminated water) levels in the past. This theory is supported by

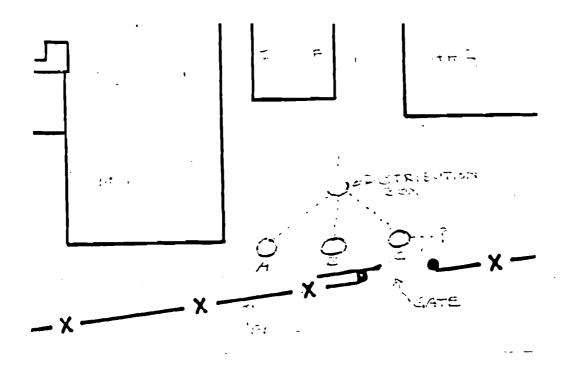


Figure 4.3.3.1. Location and Layout of Radium Injection Wells

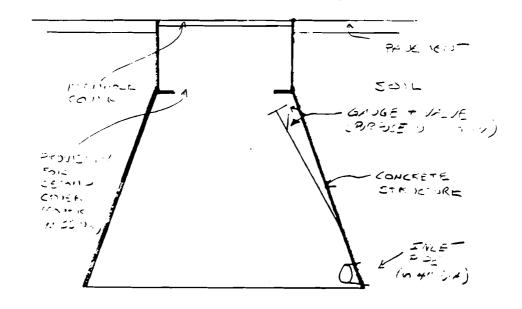


Figure 4.3.3.2. Details of Near-Surface Injection Well Features

the fact that this system was abandoned because it did not perform to the LEHR staff's expectations. It is not known if contamination has migrated from this area in the past. A relatively recent layer of blacktop has covered the old road surface in this area covering any contamination and preventing further survey efforts.

4.3.4 Radium Septic Tanks

Just south of the IMHOFF waste disposal building there is a series of four septic tanks. The covers were covered with an 8- to 12-in. layer of 2- to 3-in. rock, and tightly rusted shut. After considerable effort, they were opened for inspection. LEHR staff related that the flow of excrement was from the eastern tank through all four tanks to the west tank, and then out to the distribution box. Please refer to Figure 4.3.4.1 for the location and layout of these tanks.

Upon opening, water was discovered to be within approximately 3 ft of the top of the tank. A large steel "butterfly valve" like construction was located in the passageway to the tanks. The function of this "value" is unknown.

Of the four tanks, the water level in tanks "A" (easternmost), "B" (the next in line), and "D" (westernmost) was very similar. This would be expected of a gravity-fed, flow-through system. Tank "C" did not appear to contain any water at all. Due to the relatively high levels of both contamination (determined by ion chamber) and stench, further investigation was stopped. The only reason that has been offered for this difference in water levels is a leak of some sort in tank "C." No holes were drilled to investigate this matter as the drilling crew had departed before this matter came to light. Additionally, location of the tanks, buildings, and sidewalks in the area would make sample drilling (support and clearance for the drilling rig) quite complicated.

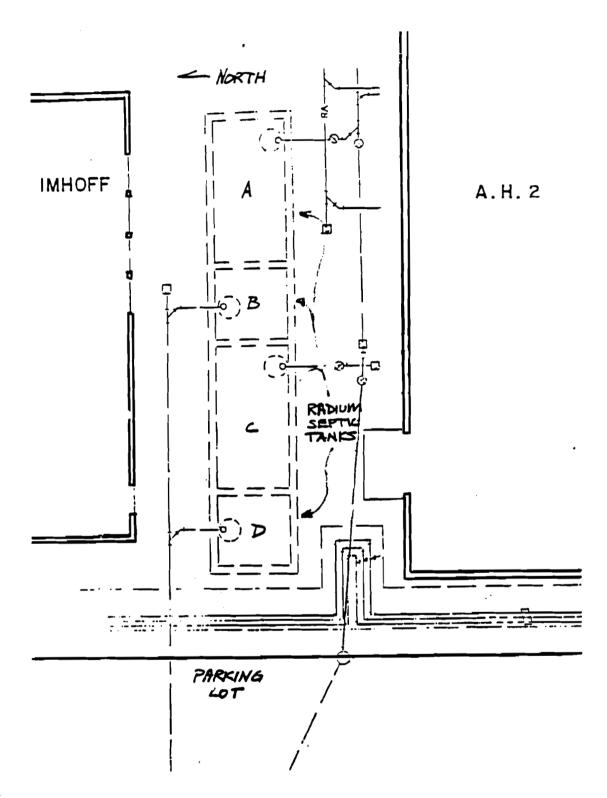


Figure 4.3.4.1. Location and Layout of Radium Septic Tanks

4.3.5 IMHOFF Facility

The IMHOFF facility is shown in Figure 4.3.5.1. This is a waste treatment facility described in Appendix A. Samples were obtained from the settling tank. Samples were not obtainable from tanks earlier in the waste processing stream due to heavy equipment being stored over the access hatches. This sample was sent to EAL in Richmond, California, for Plutonium-241 analysis. While no measurable quantities of Pu-241 were detected, there was a significant quantity of Radium-226 and/or Strontium-90 in the samples as determined by both ion chamber and gamma spectroscopy surveys. These samples exhibited a beta gamma field of approximately 2 mrad/h on contact.

Lack of access prevented boring test holes around the facility to attempt to find possible leaks from the outer ring of tanks. Two test holes were located between the IMHOFF building and the radium septic tanks on the southeast corner and the southwest corner of the IMHOFF..

A smear survey was made on this facility, and low levels of removable contamination were found.

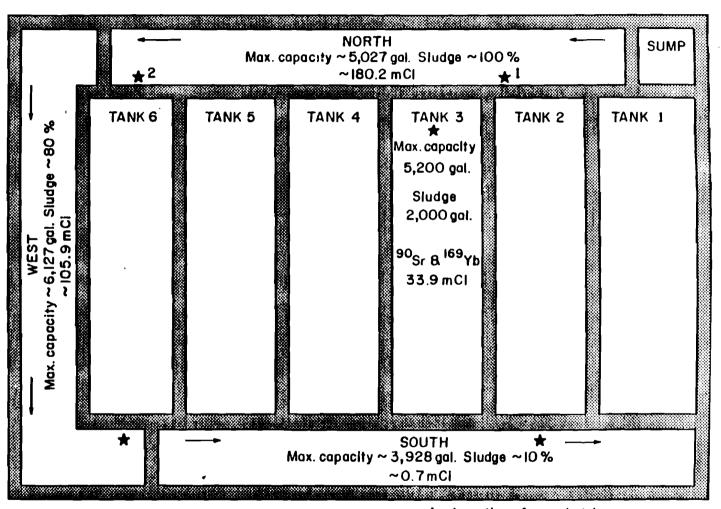
4.4 RADIOCHEMICAL ANALYSIS (SAMPLES FOR FURTHER ANALYSIS)

Chemical Analysis

No. 139 Hole 30 Depth = 20 ft
 No. 140 Hole 29 Depth = 20 ft
 No. 143 Hole 9 Depth = 20 ft
 No. 137 Hole 2 Depth = 20 ft

Figure 4.3.5.1.

The IMHOFF Facility



★-Location of sample taken

Radium-226 and Strontium-90 1. No. 81 10-ft level Hole 29 2. No. 82 15-ft level Hole 29 3. No. 83 20-ft Tevel Hole 29 4. No. 86 10-ft level Hole 30 5. No. 87 Hole 30 15-ft level 6. No. 88 20-ft level Hole 30 7. No. 91 10-ft level Hole 31 8. No. 144 Bones from No. 13 9. No. 106 10-ft level (Hole 13 grab sample composite) 10. No. 112 Dog pen samples

Plutonium

- 1. No. 135 IMHOFF Tank C
- 2. No. 134 Distribution box
- 3. No. 136 Ra Septic Tank A
- 4. No. 81 10-ft level Hole 29

Carbon-14 and tritium

٦.	No. 39	10-ft level	Hole 13
2.	No. 43	5-ft level	Hole 14
3.	No. 24	10-ft level	Hole 10
4.	No. 10	5-ft level	Hole 6
5.	No. 4	5-ft level	Hole 2

The results of these analyses are tabulated in Figure 4.4.1.

4.5 DEEP WELL SURVEY POINTS

To investigate possible migration from the Ra-226 injection wells and the IMHOFF/septic tank system, two 70-ft-deep wells were drilled by Eaton Well Drilling (of Woodland, California). The location of the wells is shown in Figure 4.5.1. Two exploratory shafts were drilled. The information obtained will aid in the design of a monitoring well to check for migration from the Radium Injection wells.

ANALYSIS OF 8 SAMPLES FROM ROCKWELL INTERNATIONAL

Customer	EAL	14C	ъĦ	226Ra	POST	24 1Pu
Sample Nos.	Dissolution No.			± 1 \(\sigma \) (\(\gamma \)		
4 41 20 mm	508-16	<16	142 ± 16			
10 um 6 .5 2	508-17	29 ± 48	208 ± 56			
24 Har 10 @ 10 FT	508-18	<19	154 ± 44			
39 - MUL 13 @ 10 ft	508-19	1.160 ± 7	171 ± 14			
43 - Hairto e erc	508-20	794 ± 4	137 ± 14			
81 - H 24 & 10F	508-1			0.204 ± 19	0.334 ± 16	<50
	508-2				0.079 ± 60	
83) 2966				0.431 ± 13		
86 H 30 @ 10ff					0.095 ± 56	
87 H 10 @ 12'	508-5			0.550 ± 13		
88 H3 e Q 10'	508-6			0.507 ± 11	0.17 ± 27	
91 H 31 C 10'	50 8- 7			0.469 ± 17	0.20 ± 62	
.06 R 13 @ 10"				3.94 ± 3	0.909 ± 6	
12 Doilon # 4				0.431 ± 12	0.852 ± 6	
34 Digitrobution Con	508-10					<50
.35 Imheff Tonk 3"	508-11					<50
36 Ra Soptic Tank of	508-12					< 50
44 feres of dee H. 13	508-13			2.35 ± 5	17.3 ± 2	
Blank (a)	508-15	<16	<25		<0.20	<50

⁽a) Blank is pCi/sample.

Figure 4.4.1. Radiochemical Analysis of Samples from LEHR

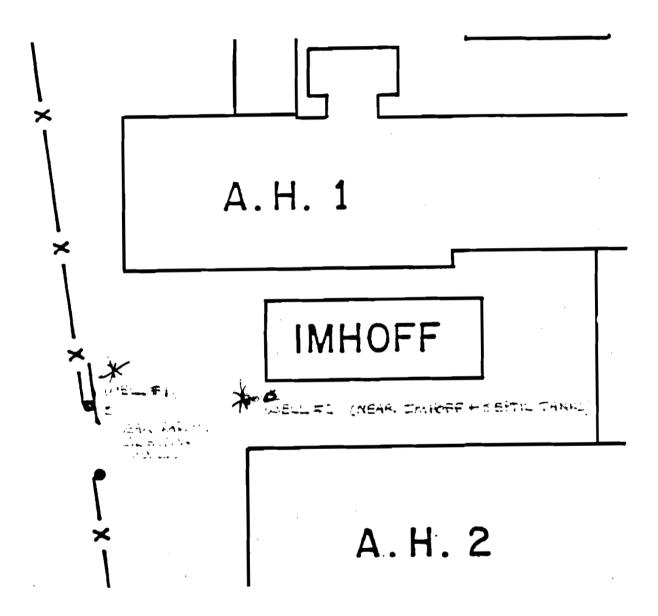


Figure 4.5.1. Location of Logging Wells

Effluent from these holes was monitored for radioactive contamination, but with the interference (by dilution) of the drilling mud, no reasonable results were expected.

The data expected was an "E-log" which measures the permeability of the soil so that a properly-designed monitoring well may be installed if the need is seen. The "E-logs" are shown in Figures 4.5.2 and 4.5.3.

To prevent contamination of ground water with surface water or between layers of ground water, the wells were sealed with cement upon completion of logging.

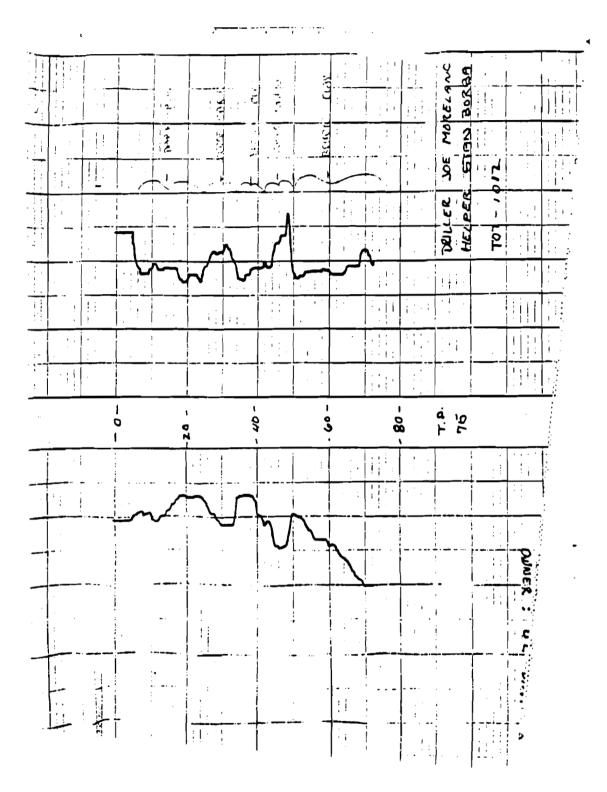


Figure-4.5.2. "E" Log for Well No. I

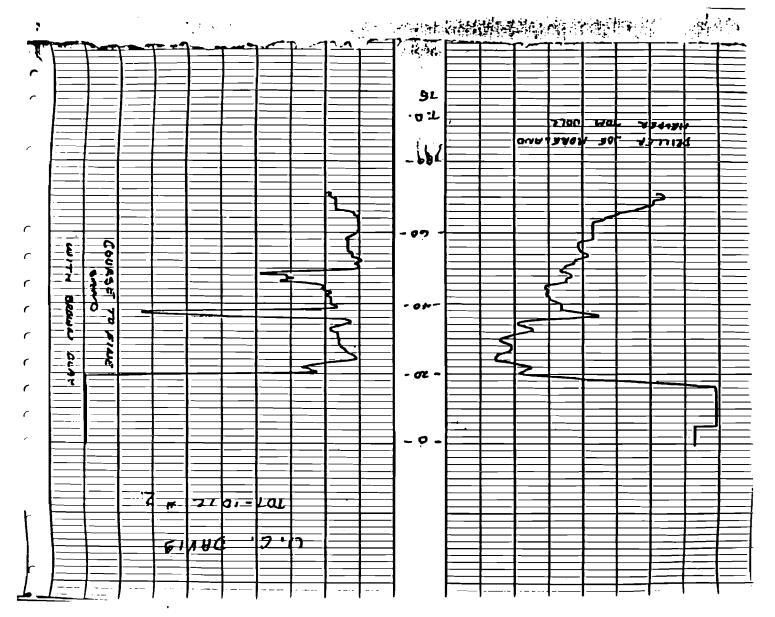


Figure 4.5.3. "E" Log for Well No. 2

5.0 DISCUSSION

5.1 CHEMICAL CONTAMINANTS

The results of chemical analysis on four (4) soil samples show no chemical contamination.

5.2 RADIOACTIVE CONTAMINANTS

As a general statement, there is no apparent loss of control of radioactive materials at the LEHR site.

There has been disposal of radioactive materials on this site in the past. Traces of tritium, Carbon-14, Strontium-90, Radium-226, and Cesium-137 were found in areas suspected as radioactive waste burial sites. Significant amounts of Radium-226 and/or Strontium-90 have been disposed of by leach fields and injection wells. Documentation as to the exact locations or quantities of materials disposed of has not been located.

There is some question as to which programs were responsible for the waste buried. While the waste was undoubtedly buried in conformance with the standards applicable at the time, the waste burial site does not conform to current standards in terms of either trench construction, licensing, or documentation. With the possible exception of tritium, no measurable migration of activity has been located.

The values recorded for H-3 (tritium) contamination present a question. The values quoted represent picocuries of tritium per gram of soil, and while not at a hazardous level, are five to ten (5 - 10) times higher than expected. The values obtained are relatively closely grouped, suggesting some relationship among the samples but these samples were so widely spaced around the physical plant of the LEHR site that the possibility of cross contamination was investigated. A careful review of procedures at both ESG and EAL did

not reveal even a possible source for the cross-contamination. In this light, we consider these tritium analysis values open to some question.

Further study to define the potential problem areas is indicated before definitive action plans can be reasonably made.

5.3 PROBLEMS ENCOUNTERED

Many problems were encountered in the course of this survey. These problems with suggested solutions for possible future efforts are noted below:

- o Lack of Communication

 Need Full Time DOE and LEHR Liaison for Survey Team
- Lack of Documentation
 Need Comprehensive Study of Site Documents
- ∨ o Gamma Field from Co-60 Irradiator Field High Backgrounds Shut Down Co-60 Field
- Meteorological Considerations (Careful scheduling of survey effort)
 (High Temperatures Caused Instrument Malfunctions)

These problems were discussed in the proposal survey plan with the exception of meteorological considerations, and had greater impact upon survey performance than expected. With careful planning, the effect of these problems can be minimized in future efforts.

6.0 ACKNOWLEDGEMENTS

Many people helped to make this difficult task possible. These persons will be valuable references for possible future investigations. We wish to thank the following persons for their assistance:

At DOE/SAN:

Chuck Taylor Phil Hill Jim Ricks

At LEHR:

Dr. Marvin Goldman
Don Ballard
Evelyn Profita
Richard Holdstock

At Rockwell/ESG:

Kit Kittinger

J. Carroll

R. Tuttle

At UC Irvine:

Jim Tripodes

At State of California Department of Health Services (Sacramento)

John Hickman

5024Y/dm

APPENDIX A

FACILITY DRAWINGS AND INFORMATION

APPENDIX A.1.1

DOCUMENTS FROM DOE-SAN

Cover letter removed that contained personally identifiable information



II. C. DAVIS RADIOLOGICAL PROBLEM

o In 1955, it was proposed by U. C. Davis to study the long-term effects of continual ingestion of SR^{90} contaminated food in beagle dogs.

The study was broken into two (2) parts to accommodate the large number of dogs required. The feeding of the first group was done during the late 1950's. The second group was fed during the late 1960's. The study consisted of dogs from conception (through the dam) unitl 18 months of age. A third group of dogs was injected with RA²²⁶ to act as a control group for the study.

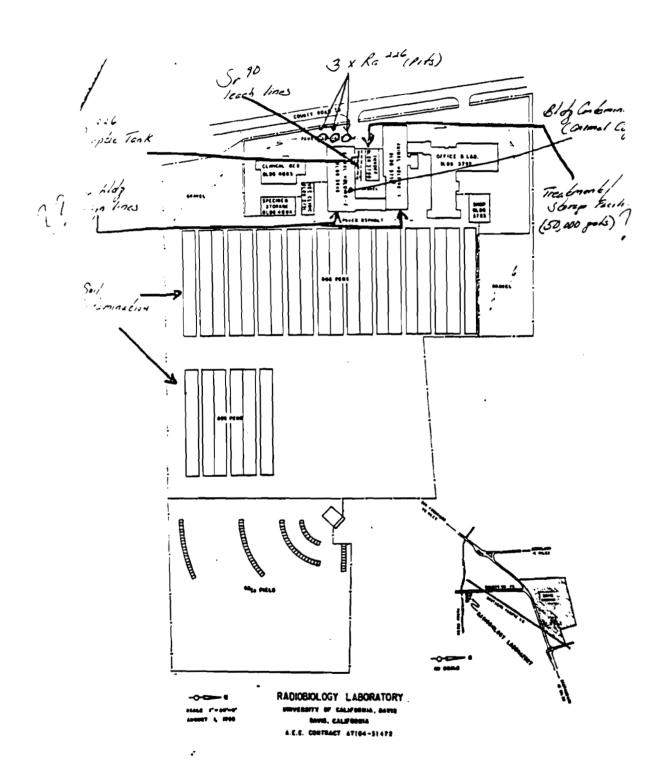
- o The SR⁹⁰ dogs were housed in cages in Bldg 3750 during the feeding period. After the feeding period, the dogs were put into pens adjacent to the building complex. Excreta from the dogs was washed from the cages each day into an imhoff settling tank. Masts water was pumped from the imhoff tank through resin filters into a leach field located near the imhoff building. Excreta from the dogs while in the pens was collected, if possible, otherwise it was allowed to wash into the soil. This system is still in use today.
- o The RA226 dogs were housed in cages in Bldg 3846 during the infection period. These dogs were also later put into the holding pens next to the building complex. Excreta from the dogs was washed from the cages each day into a septic system and them into three (3) 100 to 150 foot vertical leach wells. Excreta from the dogs while in the pens was collected, if possible, otherwise it was allowed to wash into the soil. The vertical wells are not in use at this time. Waste water exits into the facility sewer system.
- o The area the dog pens occupy was used in the early 1950's as a radioactive dump site for University experiments. The type and amount of radioactivity is unknown at this time.

POTENTIAL PROBLEMS

- o Cage and drainage system contamination for each building.
- o Laboratory and stroage facility contamination.
- O Waste treatment facilities contamination.
- o Contaminated soil around the treatment facilities because of structual cracks in the concrete structure.
- o Contaminated soil in and around the leach fields.
- o Contaminated ground water from activity in the leach fields.
- o Contamination in area sewer lines.
- o Contamination of dog pens.
- o Soil contamination under dog pens from dogs and from earlier waste burial.
- o Contamination of drainage ditches from dog pen rain run-off.
- o Possible non-radioactive hazardous waste contamination of soil and facilities.

ACTIONS

- o Provide funding for the development of a site assessment plan that will assess the radiological and non-radiological levels of activity. COST: 53K to \$5K
- Require U. C. Davis to provide to SAN all pertinent files, facility plans, purchasing records, ground water information, etc.
- o Secure a contractor to develop a plan and submit to SAM for approval.
- o Provide funding for the eite assessment and secure a contractor to undertake the assessment. COST: \$25k \$40k



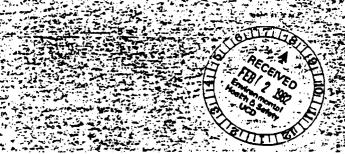
AI-DOE-13504 78

RE: Decontamination of Ra 226 Sewage System

I have been contacted by Mr. Glen Jones from Battelle Northwest Laboratory regarding the status of our Ra 220 Sewage system. As you know we have with your departmental assistance provided DOE with a decontamination of the status of our Ra 200 Sewage system. As you know we have with your departmental assistance provided DOE with a decontamination of Ra 226 Sewage System. plan and cost estimate. Mr. Jones, John Brehm and Richard Coy will be in the area February 9, 1982 and would like to stop by to familiarize themselves with the site and to assess the magnitude of the potential problem. I would like to have Evelyn Profita here to meet with these people and to have your file on the previous activities. I do not believe that any significant action will be taken since the contaminated system does not interfere with the laboratory's operation nor is it a health problem.

I will keep you posted as I get more information. problem. I would like to have Evelyn Profits here to meet with these

HGW:bju





SYSTEM DESIGN . PACKAGING . TRANSPORTATION . DISPOSAL

NUCLEAR SPECIALTIES P.O.Box 2109 Turlock, Calif. 95380 (209) 667-1102

Aug. 21, 1979



Mr. John H. Hickman R.S.O. University of Calif. Office of Environmental Health & Safety Davis, Calif. 95616

RE. D and D of Radioactive Waste Retention Tank, Radium Dry Wells, and Leach Line Ditch.

Dear Mr. Hickman:

Cost schedule covering work to be performed was exclusive of removal, transportation, and unloading of the retention tank. Heavy Transporters of Los Angels, was contacted for bid estimate. Their quotation for loading, transportation, and off loading at Nuclear Engineering, Beatty, Nevada is \$62,399.92. Bid estimate is firm till Aug. 1980.

Total cost estimate of the entire project is \$288,845.99.

Should you have any questions please call me.

Sincerely,

Robert A. Swder

RAS/kfs

October 1970

PLANNER/DEPARTMENT COORDINATION SHEET

	Dept. AFC PALL'S LOS No. 00238 Planner Coulombe Contact Lwis,
	Project delibert spictork to Spiritor M. H. Date 1-28-7
	Scope of Work Tio 10 to Exist 4" MAST THEN LINE PERMI
2	- 4" U Alace - 1 Lack Able Uplace Box, install 1 rid
	Olyanat, Back Cill W/ Poud Rook + St. 1.11
	Connote walk and putak asit if Demines
	Copiner axisting cribble
	Order of Magnitude Cost for Work Requested \$\frac{\pi_1700^{69}}{2}
	Does the department have sufficient funds to complete the work requested?
	Remarks ENACT LOCATION OF UTILITIES in AREA MAC 1
	Kinging this is a possibility of Encertains
	12301665 AT time of averagetion which may income
	Λρρτονals By: × L []
	Buildings A&E Fire Env. Health Space Utilities
	I agree with the preliminary plan as presented; the cost for the work requested is
	reasonable, and I intend to proceed with the project. I request that the Planning and
	Engineering Branch of the Physical Plant Department proceed to develop a detailed
	work plan and material list to complete the work.
	J. M. Elinia
	Y I week II held the

Attachments



Department of Energy San Francisco Operations Office 1333 Broadway Oakland, Caiifornia 94612

April 17, 1979

Dr. Marvin Goldman, Director Radiobiology Laboratory University of California Davis, California 95616

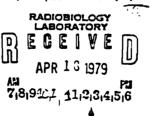
Subject: DECONTAMINATION AND DECOMMISSIONING OF RADIOACTIVE WASTE RETENTION TANK, RADIUM DRY WELLS AND LEACH LINE DITCH

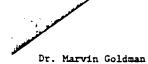
Dear Dr. Goldman:

The subject facilities have been added to the DOE surplus nuclear facilities list. At this time additional information on the facilities is needed for inclusion in the 20-Year Plan for Decommissioning of DOE Radioactively Contaminated Surplus Facilities.

Please provide us with the following information in a five or six page technical report by May 31, 1979.

- 1. Description of facility.
- 2. Description of decommissioning mode (dismantling).
- 3. Tasks to be performed for the project (plan, site preparation, etc.).
- 4. Cost and schedule for work to be accomplished by fiscal year.
- 5. Manbower requirements (man years of effort).
- 6. Projected occupational exposure.
- Projected volume of waste to be generated in feet³ (concrete, soil, steel, etc.) and disposel site.
- Reference any other documents which provide information about the decormissioning of facility (i.e., surplus facility questionnaire).





April 17, 1979

You will note that some of the information requested was developed for the surplus facility questionnaire which you provided on July 28, 1978. Information may be abstracted from this document for this report.

If you have any questions, please call Hattie Carwell at FTS 536-7963.

Sincerely,

and C. fram

Calvin D. Jackson, Director Environment and Safety Division

Pages 85-87 removed Resume removed: contained personally identifiable information

Pages 85-87 removed Resume removed: contained personally identifiable information

Pages 85-87 removed Resume removed: contained personally identifiable information

23 October 1970

TO:

FROM:

SUBJECT:

levels in septic tanks connected to AH-2

LOGI LABORATORE

The subject tanks have been used for the past 7 years in the radium administration phase of our experiment. Several millicuries of radium-226 have entered these tanks and it would be to the laboratory's best interest at this time to determine what the total content of radium-226 is in these tanks. In view of the several years worth of nonradioactive excreta that have most recently gone through the system, there is a very good chance that a substantial fraction of the initial radium content has been flushed on into the dry wells.

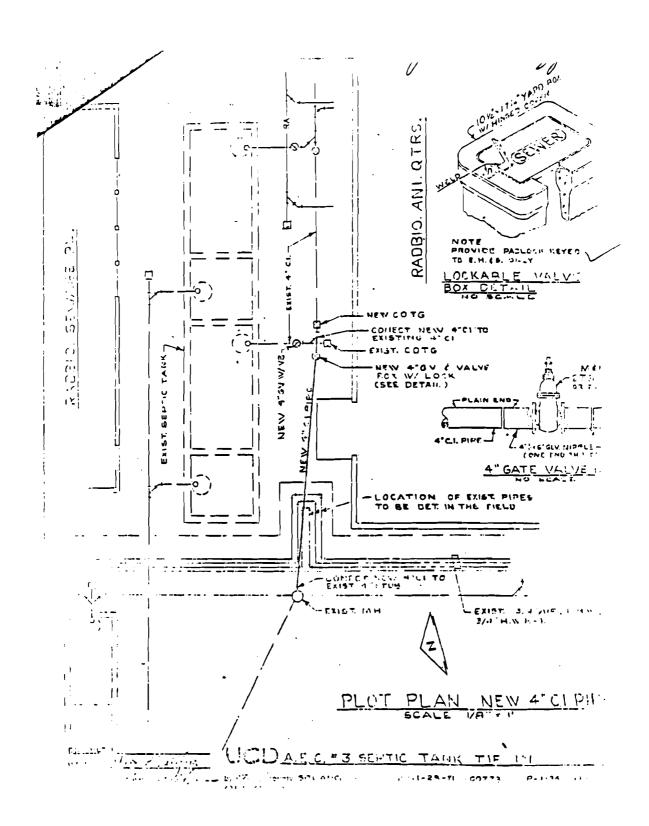
The amount remaining in the sludge at the bottom of the tank, in suspension in the fluid mass or entrapped in the floating mat of organic material on the surface of each of the two tanks should be evaluated at this time, as these represent a level that is not likely to change markedly in the foreseeable future under current operating conditions. The imminent contract to connect the influent lines to a new sanitary sewage system requires tapping into the line between AH-2 above to the septic tank and it is of importance to the University that we verify the level of radioactivity presently in this line.

I, therefore, recommend that any clean-out traps that exist in the line be opened at a convenient time during the day and samples be obtained of the sludge and coating and/or contents at these points, particularly those closest to the point of line interruption and valving to the new system. There is a chance that we may be requested to transfer the contents of the two septic tanks to some outside burial pit, although my present inclination is to leave the tank in its present state. An intelligent judgment can be made about the disposition of the system after the above-mentioned samples within the septic tanks as well as the influent lines have been obtained and measured. It would also be useful to determine what the volume in the two tanks is at the current time, as well as what their capacity is.

MG:kjr

cc: J. M. Stone H. G. Wolf L. K. Bustad

UNIVERSITY OF CALIFORNIA-(Letterhead for interdepartments) see) - Coppe



AI-DOE-13504 89

NO /

April 5, 1965

Dr. A. C. Anderson

Ro: Sub-Surface Sowage Disposal System for New Wing of Animal Quarters.

126.1116

As per our conversation of March 30, 1965, with Dr. Goldman, we wish to express our concern over the frequent failures of the seepage pit system designed for acceptance of waste from the second indeer unimal unit. It now appears that the septic tank system is functioning adequately, but the damage done to the pits during the time of the septic tank failure, is still causing trouble. It occurs to us that the ultimate solution may be the installation of a more adequate subsurface drainage system. However, we feel that hefore going to this expense, some more information should be gathered. For this reason we ask that you institute the following system of tests and controls:

- Re-charge the three seepage pits with concentrated sodium hydroxide as before, to determine how long it will take for the pits to send up again.
- Institute a sampling procedure for the determination of R.O.P. removal and suspended solids removal from the sertic tank system. We suggest that samples be collected from the influent portion of the tank and from the distribution how each Monday, Pednesday and Priday until a pattern can be observed.
- 3. Establish a routine inspection program of the system, including determination of the water level in the pits by means of the depth gauges provided by the contractor. Inspection can be accomplished at the time of the sample collection, and should include determination of the depth of the ent in the first compartment of each tank, observation of the water level in the second compertment in relation to the elevation of the outlet T, verification of water flow through the distribution box.

In this way, we believe we can be assured of the proper functioning of the septic tank so as to prevent damage to future systems.

Richard S. Holdstock, R.S.

The Market

RSH: db

cc: Dr. Harvin Goldman

TOI

Fred Cooper

FROM:

M. Goldman

SUBJECT: AEC Project Waste Disposal

In the light of our current expansion, we would like to review some aspects of radioactive wasta disposal with your office and obtain your comments on certain proposals.

- 1. Current status Only Sr⁸⁰ wastes are being produced by our dogs. Waste treatment plant operating on a 20 day cycle is discharging about 5-10 ac Sr⁸⁰ per year to the leaching field following ion exchange. Expended resins are disposed of commercially.
- 2. Future status A. Waste treatment plant will accelerate discharge rate and deposit about 10-15 µc Sr⁹⁰/year from a 10 day cycling period.
 - B. After feeding period of $\rm Sr^{90}$, dogs will be maintained in outside pens on non-radioactive food. Their body burdens will decrease causing surface contamination at a maximum rate of 3 $\rm uc~Sr^{90}/da$. Half of this will be urinary and deposited on the soil. Half will be fecal excreta which is removed daily. Thus over the 4 year effective pen period, an average of 500 $\rm uc/yr$ of urinary $\rm Sr^{90}$ plus 500 $\rm uc/yr$ feces are to be considered.
 - N.B. The project site now contains about 800 μ c Sr⁹⁰ as a result of atmospheric nuclear detonations. (About 200 μ c on pan surface area).
 - C. It is proposed that the daily fecal waste (about 35 Kg/da) be buried in an appropriate sanitary ditch without radiologic safeguards being imposed. Decomposition will result in an essentially massless "vein" of Sr^{90} at this site. If radiologic rules prevent such handling, it is alternatively suggested that the waste be segregated with the 3 highest levels receiving special handling. (These will contain 90% of the waste in about 1/3 the total volume).
- Ra³²⁶ Injections.
 - A. A similar series of dogs (180) will each receive 8 equal Ra²³⁶ injections over a five month period. During this time they will be confined in special cages. Of the total 5.3 Mc Ra²³⁶ injected about 3.5 will be excreted and must be disposad of. (Ret = 0.8t⁻⁶²). If all concentrated, waste would emit ~ 30 R/hr at 1 cm!)
 - B. Cleaning cages daily will produce a minimum of 27,000 liters of waste. Add one 1/dog/da for washing and yield is 60,000 gallone at 0.7 µc Ra/1; enough to fill 530-30 gallon drums (@ \$48 ea) for a cost of \$25,500 plus labor.
 - C. It is proposed that daily fecal waste be manually removed and packaged for offsite burial. (180 dogs x 200 g/ds/dog) \approx 40 Kg/da. Urine will be collected in 30 gal drums. Cage washings will be collected in a separate 10-15,000 gal septic tank for ultimate

disposal or discharge based on level. This could be processed by ion exchange and the effluent discharged underground while the resins are disposed of off site.

D. Since soil contains 10^{-12} g Ra ²³⁶ per g soil naturally, if concentration is avoided through use of long leach lines, soil Ra²³⁶ content would not be seriously raised. An acre foot of soil contains ~ 2 x 10^{3} Kg soil or about $(2 \times 10^{3}$ g)(10^{-12} g Ra) ~ 10^{-3} g Ra = 1 Mc Ra²³⁶/acre foot. Over the 10 year project life spans, the urinary Ra²³⁶ deposited on the 2 acrea of pen surface (to a foot depth will be about 500 uc Ra²³⁶ or one half of what is present now. This is an upper limit since most of the highest dogs will not live for 10 years).

E. It is proposed that the $\rm Ra^{226}$ fecal waste (a total of about 500 $_{\rm HC}$ $\rm Ra^{226}$ in 10 years be buried locally in a similar fashion to 2 C above.

N.B. Feeding regulations permit 1.2 Mc/yr burial of $\rm Sr^{90}$ + $\rm Ra^{236}$.

- F. Decisions are requested on the following. 1. Can $Sr^{90} + Ra^{38}$ wastes be discharged to underground leach lines.

 2. Can Sr⁹⁰ + Ra²⁸⁸ be buried locally.

 3. What are the limits for \$ 6.2.

 - 4. What campus policies exist in these matters.

MG/mc

80226 - 100 per/series.

October 9, 1962

. 00 1

Richard H. Rohrbach

Subject: Design Criteria for Absorption Trench-ASC Project No. 6. (& com)

As per our previous discussion, we have completed percolation tests to establish design criteria for a deep absorption trench for the effluent from the ARC Project No. 6 Sewage Disposal Plant. Due to the high degree of treatment afforded the effluent from this plant, it was decided not to use the standard conversion factor for septic tank effluent (4.5 of the clear anter rate). Instead of the 4x figure, it was decided that 10x would offer a reasonable margin of safety. Provided the field is installed as outlined abolow, there will be sufficient area amilable for 100x replacement of the initial system, if the 10x figure should appear to be too liberal.

The absorption system should consist of a 40' long, 6' deep, and 2' wide trench, with a 4' layer of 4" to 8" cobbles in the bottom, covered with a 6" layer of 2" to 3" gravel. Four inch open irrigation tile or 4" crongeburg should then be leveled and centered down the entire length of the trench. The 2" to 3" gravel should then be filled around and to 2" above the tile or orangeburg. The rooks should then be covered with two inches of baled straw and backfilled with dirt to three inches above the level of the surrounding ground. Since it may prove necessary to add gyroum to the leaching field, a man hole with a tight sealed cover should be installed close to the conter of the 40' line, to act as a distribution box. The field should be located 10' from any buildings and preferrably as close to the Sewer Plant as possible.

Since this system is to replace an existing leach field, we would approxiate being advised of the time that construction will correcte, so that we can keep problems due to over flowing sewage to a minimum,

Richard S. Heldatock
Engironmental Health & Safety Technician

Ration co: A. W. Huff

October 9, 1962

Richard H. Rohrbach

Subject: Design Criteria for Absorption Trench-AEC Project No. 6. (16 cham)

As per our previous dissussion, we have completed percolation tests to astablish design criteria for a deep absorption treach for the effluent from the ARC Project No. 6 Sewage Disposal Plant. Due to the high degree of treatment afforded the effluent from this plant, it was decided not to use the standard conversion factor for septic tank effluent (%) of the clear state rate). Instead of the 4% figure, it was decided that 10% would offer a reasonable margin of safety. Provided the field is installed as outlined below, there will be sufficient area available for 100% replacement of the initial system, if the 10% figure should appear to be too liberal.

The absorption system should consist of a 40° long, 6° deep, and 2° wide trench, with a 4° layer of 4" to 8" cobbles in the bottom, covered with a 6" layer of 2" to 3" gravel. Four inch open irrigation tile or 4" crangeburg should then be leveled and centered down the entire length of the trench. The 2" to 3" gravel should then be filled around and to 2" above the tile or orangeburg. The rocks should then be covered with two inches of baled straw and backfilled with dirt to three inches above the level of the surrounding ground. Since it may prove necessary to add gyroum to the leaching field, a san hole with a tight sealed cover should be installed close to the center of the 40° line, to set as a distribution box. The field should be located 10° from any buildings and preferrably as close to the Sower Clant as possible,

Since this system is to replace an existing leach field, we would appreciate being advised of the time that construction will correcte, so that we can keep problems due to over flowing sewage to a minimum.

Richard S. Heldstock
Environmental Health & Enfety Technicism

Riffi wh

2,000 (No. 8)

DAVIS: SCHOOL OF VETERINARY MEDI

December 20, 1960

Dr. Fred N. Cooper Student Health Campus

Dear Fred:

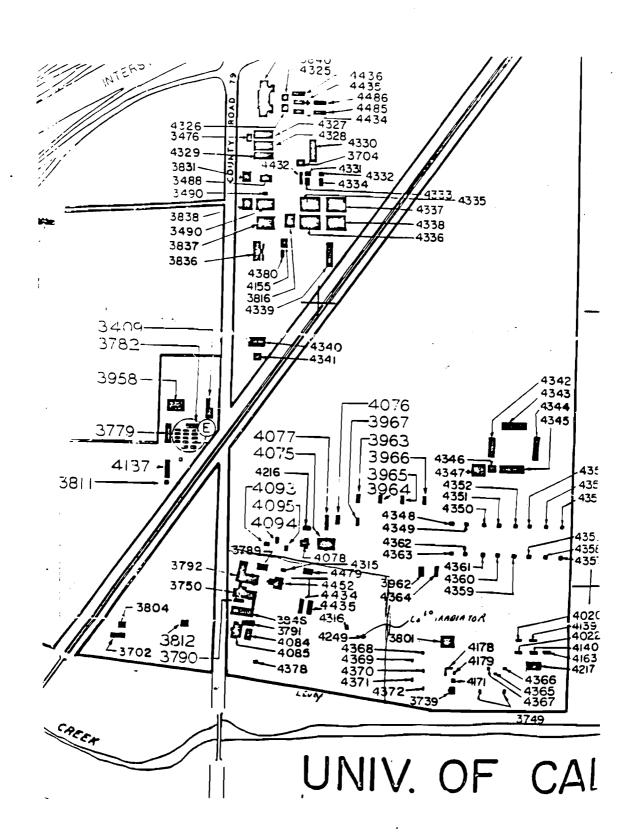
We now ere ready to begin our chronic $\rm Sr^{90}$ feeding program. As you know, we have conducted several tests of our facilities over past months, and, Dr. Kaufman recently reviewed the radioective disposal system. His suggestions for increasing the efficiency of operating this system have been completed as described in the enclosed letter. We ere starting the experiment with dose level 0.3, which is our lowest (MPC) $\rm Sr^{90}$ treatment, and one that will enable a final check with minimum hazards before attempting to start higher dose levels.

If you have any suggestions, please contact me. Also, we would be delighted to have you visit the project whenever it may be convenient.

Sincerely,

A.C. Andersen, VMD, PhD

ACA/c



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APPENDIX A.1.2

DOCUMENTS FROM LEHR (IMHOFF SLUDGE DATA)

IMHOFF SLUDGE SAMPLE 5/123/84

10 Min Counts			Net Counts	
Background	3 liter		17,034	
Standard		0.9 µCi	64,524	47,490
North 1	•		1,384,984	1,384,984
North 2	w		1,647,217	1,630,183
West	•		921,140	904,106
South	•		89,980	72,946
Tank 3	•		729,269	709,235

Sample activity =
$$\frac{\text{Standard } \mu\text{Ci} \cdot \text{Net Samples cnts}}{\text{Standard net cnts}} = x \mu\text{Ci/liter}$$

Total gal - 3.785 \pm /gal - \times μ Ci/ \pm = total μ Ci activity

North average counts

1.499.067

Sample activity =
$$\frac{(0.9)(1.499.067)}{47,490(3)}$$
 = 9.47 µCi/L

(5,027)(3.7853)(9.47) = 180,202 uC1 or 180.2 mCi

Hest

Sample activity =
$$\frac{(0.9)(904,106)}{47,490(3)}$$
 = 5.71 µCi/L

 $(4,901)(3.7853)(5.71) = 105,944 \mu Ci or 105.9 mCi$

South

Sample activity =
$$\frac{(0.9)(72,946)}{47,490(3)}$$
 = 0.46 µCi/z

$$(393)(3.7853)(0.46) = 684 \mu Ci or 0.7 mCi$$

TANK 3 Sample activity = $\frac{(0.9)(709,235)}{47,490}$ = 4.48 µCi/2 (2,000)(3.7853)(4.48) = 33,916 µCi or 33.9 mCi

Total Sludge = 12,321 gal. Total Activity = 320.7 mC1/z

IMHOFF DIMENSIONS

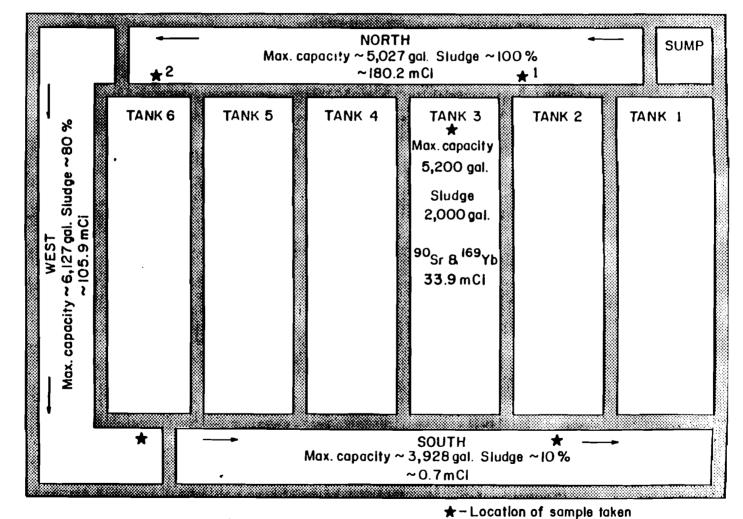
Depth 6.0 ft.

Width 3.5-ft.

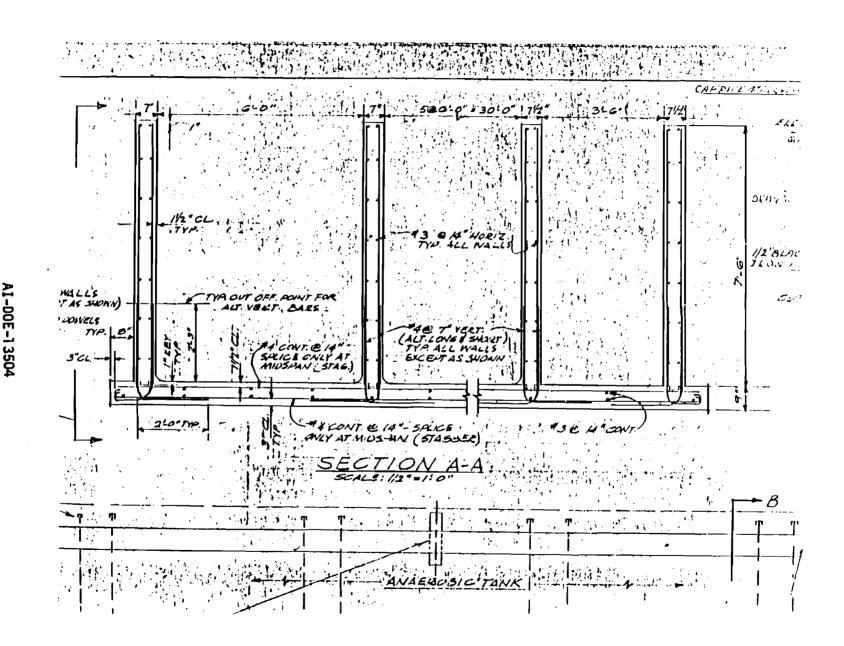
North 32.0 ft.

West 39.0 ft.

South 25.0 ft.



and the contract of the contra



ACQGRP TOTAL LIVE REAL QUAD BKG 3 LI	10000000 00: 10: 00 00: 00: 00 0: 000	ADC SLOPE	5023 00:10:00 00:10:00 1:000	23-MAY-84 23-MAY-84 ZERO		08: 33: 26 08: 23: 26 0. 000		•
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33: 41:	297 171	287 189	289 175	204	220 173	192 176	181 173	171 220
49:	205	220	197	186	149	150	151	156
57 :	158	149	125	127	150	117	118	117
65 :	107	108	100	106	106	99	88	112
73:	89	88	63	84	93	68	104	101
81:	102	84	91 87	91	94	8 4 97	8 4 73	78 79
89: 97:	25 72	90 70	97 73	85 62	80 63	56	67	64
105:	56	70 72	64	- 77	62	71	59 58	68
113:	70	65	66	48	60	61	59	46
121:	68	61	56	45	40	47	51	57
129:	44	34	46	51	35	43	42	52
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177	24	29	21	23	34	26	25	16
185:	17	10	24	20	32	18	30	14
193:	23	14	19	16	18	18	18	13
201:	16	20	13	11	9	14	16	18
209:	15	16	24	24	28	20	23	25
217:	23	26	19	14	16	23	17	14
225:	18	15	7	17	21	10	14	12
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ACQGRP TOTAL LIVE REAL QUAD SR 90 WA	1 10000000 00:10:00 00:00:00 0,000 ASTE STD	ADC SLOPE	1 6481 00: 10: 00 00: 10: 00 1: 000	23-1	1AY-84 1AY-84 	08: 22: : 08: 12: : 0. 00	24	
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177; 185; 193; 201; 209; 217 225; 233; 241;	23 25 17 24 24 16 18	17 19 27 17 12 26 14 13	25 20 19 14 14 19 20 19 22	25 15 18 22 25 12 12	18 22 17 21 23 23 11	23 12 13 23 26 20 19	22 20 27 24 19 17 16	12 26 18 16 18 11 17

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137: 145: 153: 161: 169: 177: 185: 193: 201: 209: 217: 225: 233: 241:	160 151 70 59 76 68 46 17 23 31 22 21 19	148 141 95 74 56 51 39 29 26 20 24 21 20 17	160 136 94 70 74 58 36 34 21 34 23 24 20 13	135 144 69 74 83 63 31 25 21 25 21 25 20 23	160 130 56 66 65 59 32 28 21 26 28 20 16	154 105 59 69 83 32 35 27 27 26 30 19 10	151 126 72 78 89 31 29 16 25 26 16 22 16	154 86 66 73 69 53 24 22 24 28 17 12

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17:	45210	40450	36698	33121	29724	27690	25216	23315
25:	21209	19695	13037	16974	15747	14621	13520	12736
33:	11844	11334	10335	9652	9081	8632	7908	7498
41:	7046	6698	6405	6101	5664	5432	5256	4974
49:	4878	4648	4414	4141	3842	3673	3473	3198
57 :	3094	3024	2897	2 73 3	2708	2637	2359	2366
٤5 :	2168	2123	1969	1940	1777	1782	1666	1597
73:	1499	1473	1452	1410	1255	1296	1139	1162
81:	1134	1128	1034	999	8 96	965	957	882
89:	770	799	774	798	767	679	641	590
97:	600	542	591	576	513	489	505	479
105:	509	419	460	403	401	390	374	402
113:	351	347	3 55	294	3 28	302	299	244
121:	270	305	247	241	214	235	229	230
129:	192	190	203	177	205	174	166	187
137:	182	147	134	179	160	137	158	139
145:	130	141	141	125	114	120	111	100
153:	72	?5	86	78	71	69	63	67
161:	51	49	72	61	56	59	56	62
169:	62	58	59	65	65	74	63	65
17 7 :	53	45	48	47	41	45	36	33
135:	29	37	- 33	29	31	32	16	20
193:	25	25	31	22	20	16	19	21
201:	22	26	23	21	22	14	22	31
209:	26	21	27	32	18	36	20	36
217:	27	23	22	25	22	29	24	15
225:	19	10	15	21	6	13	16	13
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9:	65226	57647	50578	45390	39975	35232	31679	28194
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25:	11803	11086	10139	9525	8918	8329	7467	736 5
33:	6775	6374	5937	5601	5022	4869	4510	4330
41:	4036	3760	3658	3393	3145	3188	2995	2926
49:	2730	27 5 6	2613	2 45 2	2258	2140	1925	1926
5 7:	18 2 1	1766	1764	1616	1585	1492	1355	1367
65:	1271	1336	1203	1130	1000	1023	986	887
73:	931	905	808	840	826	741	656	637
81:	625	644	636	571	567	608	502	578
89:	519	486	441	494	456	455	417	403
97:	402	368	346	367	349	351	321	300
105:	310	298	274	278	265	257	293	263
113:	239	228	222	227	223	185	201	196
121:	155	159	160	142	156	130	128	158
129:	171	153	139	132	156	144	131	139
137:	119	146	122	126	106	129	113	101
145:	122	107	102	92	90	86	63	74
153:	53	75	64	56	62	61	50	58
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169:	54	59	51	66	50	61	55	65
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105: 112: 121: 129: 137: 145: 153: 161: 169: 177: 185:	93 85 63 49 66 63 42 31 36 35	96 81 54 66 43 59 46 34 35 13	79 82 74 47 61 71 35 36 30 34 22	62 69 56 51 64 58 35 29 37 34 22	92 85 66 77 73 43 40 25 24 25 27	84 80 66 68 51 51 39 37 32 24 32	79 69 55 84 76 37 38 30 36 23	85 73 67 61 58 37 24 32 30 35
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25:	9 579	8600	8242	8854	9988	10259	8489	6200
33:	4156	3152	2772	2370	2255	1917	1701	1470
41:	1331	1290	1169	1141	1084	1033	1002	1031
49:	958	875	90 8	237	765	729	673	639
57:	655	627	598	617	600	552	518	494
<u>د</u> 5:	463	426	440	405	411	355	383	311
73:	330	352	330	311	299	307	309	255
91:	257	248	250	229	230	231	208	198
89: 07:	187	198	211	187	180	175	164	171
97:	171	163	177	169	167	174	126	121
105:	133	123	118	116	138 133	129	133	154
113: 121:	128	148	129	124 73	133 85	109 81	117 77	107 92
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161:	44	47	47	34	38	29	36	51
169:	33	40	47	40	36	47	42	51
177:	62	46	. 33	45	40	29	30	31
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201:	18	21	32	18	.8	15	15	18
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APPENDIX A.2.1

LIST OF AVAILABLE DRAWINGS

PROJECTRADIOBIOLOGY LABORATORY	CAAN 3750, 3792, 3846
STRONTIUM 90 PROJECT	PAGE 1 OF

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DRAWING TITLE	DWNG. NO.	INGEX NO.
PHASE #1 (1958)		
Plan Diam and Bandin	1-1	01/10
Location Map, Plot Plan and Details	A-1	01419
Floor Plan and Elevations	A-2	01420
Incerior Elevations	A-3	01421
Window and Door Details	A-4	01422
Window and Door Details	<u> </u>	01422
Typical NOtes and Details	S-1	01423
Foundation and Roof Framing Plans	<u>S-2</u>	01424
Plot Plan and Details	E-1	01425
Electrical Floor Plan and Schedules	E-2	01426
Plumning Plan and Details	H-1	01427
Find the Fian and Decays		01427
Heating and Ventilating Plan	M-2	01428
Sections and Details	<u>H-1</u>	01429
Underground Plumbing Piping, Floor Plan	_	02837
Sire Plan and Location of Underground Urilities as Installed	3284/1	04009
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PIUPLT.-PAE (5/50) S94

PROJECT .	RADIOBIOLOGY LABORATORY	_)220	CAAN _	3750,	3792.	3846
	STRONTIUM 90 PROJECT	- 3	PAGE _	2	OF_	

DRAWING TITLE	DWNG. NO.	INDEX NO.
PHASE #2 (1960)		
Plot Plan and Elevations	A-1	03010
Floor Plan	A-2	03011
Interior Elevations	A-3	03012
Interior Elevations	A-4	03013
Sections	A~5	03014
Abbreviations and Details	A-6	03015
Structural - General Notes and Details	S-1	03016
Structural - Foundation Plan and Details	S-2	03017
Structural - Roof Framing Plan	S-3	03018
Structural - Sections	S-4	03019
Mechanical - Plot Plan and Details	H-1	03020
Clarification of Utilities	X-1	04570
Utility Revisions - Partial Plot Plan	X-7	04576
Mechanical - Plumbing Plan	H-2	03021
Mechanical - Waste and Ductwork Diagrams	H-3	03022
Mechanical - Heating and Ventilating Plan	H-4	03023
Mechanical - Hearing and Ventilating - Sections and Details	H-5	03024
Mechanical - Fire Sprinkler System	M-6	03025
Electrical - Plot Plan and Schedule	E-1	03026
Electrical - Power Distribution Diagram	E-2	03027
Electrical - Lighting Floor Plan	E-3	03028
Electrical - Power and Signal Floor Plan	E-4	03029
Underground Utilities Ducts and Conduit	3392/1	04008
Biochemistry Lab Table Utilities	X-2	04571
Revised Paving Plan	X-1	04572

PH.PLT.-P&E (5/60)

INDEX OF DRAWINGS AND MICROFILMS	FIHALE # 2
PROJECT RADIOBIOLOGY LABORATORY	CAAN 3750, 3792, 3846
STRONTIUM 90 PROJECT	PAGE OF

	America - 1: a	
DRAWING TITLE	DWNG. NO.	INDEX NO.
PHASE #2 (1960) cont'		
Casework Revision - West Wall, Histology #19	X-4	04573
Revised Detail H-2 from Sheet S-2	X-5	04574
Francisco of Hadden Lines for Francis Clab to Pa 10	X-6	0/575
Excention of Utility Lines for Future Sink in Rm. 10	A-6	04575
Mech. Alter.: Rms. 104, 110, 112, 115	P-820	09566
Mech. Equip. Enclosure Roof Plan & Roof Framing	P-1556-1	10818
Mech. Equip. Enclosure Section, Elevations & Brackets	P-1556-2	10819
Mech. Equip. Enclosure Section, Elevations & States	1-1330-2	10819
Mech. Equip. Enclosure Details	P-1556-3	10820
Mech, Equip, Enclosure Louvers & Details	P-1556-4	10821
Mech. Equip. Derails	P-1557-5	10822
TIEGHT DOUGLA DELATIA	1 - 1 - 1 - 1	10022
Room 112. New Ceiling, Ducts & Light Fixtures	P-1598	11477
Room 110, Partition & T-Bar Ceiling	P-1371	11573a
Replace fluorecacent fixtures	P=1775	10670
		125780
		
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PH.PLT.-P&E (5/88)

-	STRONTIUM 90 PROJECT	E Z ZAHQ	PAGE4	OF	
PROJECT	RADIOBIOLOGY LABORATORY		CAAN 3750.	3792,	3846

DRAWING TITLE	DWNG. NO.	INDEX NO.
PHASE #3 (1962)		
Additions - Plot Plan: Door, Window and Finish Schedules	A-1	04577
Additions - Floor Plan	A-2	04578
Additions - Exterior Elevations and Details	A-3	04579
Additions - Interior Elevations	A-4	04580
Additions - Cabinet Sections and Septic Tank Details	A-5	04581
Augitions - Roof Plan and Details	A-6	04582
Additions - Window and Door Details	A-7	04583
Additions - Miscellaneous Details	A-8	04584
Additions - Cage Plan and Sections	A-9	04585
Additions - Cage Details	A-10	04586
Additions - Miscellaneous Details	A-11	04587
Additions - Structural - General Notes	S-1	04588
Additions - Structural - Foundation Plan	S-2	04589
Additions - Structural - Foundation Details	S-3	04590
Additions - Structural - Roof Framing Plan	S-4	04591
Additions - Structural - Roof Framing Details	S-5	04592
Additions - Structural - Roof Framing Details	S-6	04591
Additions - Mechanical - Plumbing Plot Plan and Details	M+1	04594
Additions - Mechanical - Plumbing Plan and Details	H-2	04595 ~
Additions - Mechanical - Heating and Air Conditioning Plans	H-3	04596
Additions - Mechanical - Mech. Room #30 Details	H-4	04597
Additions - Mechanical - Details	H-5	04598
Additions - Mechanical - Details	H-6	04599
Additions - Mechanical - Equip. Schudule and Control Diagram	H-7	04600
Additions - Electrical - Plot Plan. Schedules and Decatle	F-1	04601

PH.PLT .- P&E (5/60)

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PROJECT RADIO	BIOLOGY LABORATORY		CAAN 3750,	3792, 3846
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DRAWING TITLE	DWNG. NO.	INDEX NO.
PHASE #3 (1962) cont'		
Additions - Electrical - Panelboard Schedule, Details & Diag	rams E-2	04602
Additions - Electrical - Lighting Floor Plan and Details	E-3	04603
Additions - Electrical - Power and Signal Floor Plan	E-4	04604
Additions - Fire Sprinkler - Plan and Details	FS-1	04605
Additions - Fire Sprinkler - Plan	FS-2	04606
Additions - Addendum - Utilities Clarification	X-1	04607
Additions - Addendum - Cooling Tower, Water Treatment	X-2	04608
Additions - Addendum - Kitchen #6, Sink Along West Wall	X-3	04609
Additions - Addendum - Revisions to Plumbing Sheet H-2	X-4	04610
Additions - Addendum - Revised Sect. J-5 and K-5, Sheet S-5	X-5	04611
Additions - Addendum - Rev. Cooling Tower Piping Diagram	X-6	04612
Additions - Addendum - Plan of Mech. Room #30	X-7	04613
Additions - Addendum - Revised Lighting Plan, Rec #3	X-8	04614
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COMPARISON OF THE CARCINOGENICITY OF RADIUM AND BONE-SEEKING ACTINIDES†

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(Received 18 October 1982; accepted 17 August 1983)

Abstract—The relative effectiveness of nine bone-seeking radionuclides with their progeny for the production of malignant skeletal tumors (mostly osteogenic sarcoma), principally by chronic alpha-particle irradiation, is examined with available data obtained from lifetime studies at three laboratories of pure-bred beagles exposed to graded dosages in controlled experiments. The lifetime tumor dose-rate time-response relationships observed in beagles injected with 226Ra at the University of California at Davis, in which 123 cases of bone cancer (98% osteosarcoma) have been observed for dose rates between 0.05 and 20 rad/day, provide the basis for comparing the induction of bone cancer by the other radionuclides. All nine radionuclide studies were found to demonstrate with high precision ($\sigma_{c} < 1.2$) a threedimensional lognormal response relationship represented in two dimensions by the equation of the time to death from bone cancer $t = KD^{-3}$, where t is the elapsed time to death. Dis the average skeletal dose rate, K is a parameter characteristic of the radionuclide, risk level and exposure details, and S observed to be 0.29 (0.01 SE) and suggested to be exactly one-third for all the nine radionuclides. The results show the relative biological effectiveness (RBE) for bone-cancer induction potency with respect to radiation exposure from ²³⁸Ra to be 3.0 for ²³⁹Ra, 6.4 for ²⁴¹Am, 6.6 for ²⁴²Cf, ²⁵²Cf and ²⁵³Es, 9.0 for ²⁵⁵Pu, 10.7 for ²⁵⁵Th, and 15.5 for ²³⁸Pu. The observed RBE values are interpreted in terms of the relative exposure of sensitive cells of the skeleton since they all involve primarily alpha irradiation. Scaling to people is accomplished using a response ratio (RR) of 3.6 with respect to beagles.

NOMENCLATURE

- D the average radiation dose rate (rad day) to skeleton for a given bone-seeking radionuclide from beginning of exposure until death for an individual combining energies from alphas, betas, fission product and recoil nuclei
- E the average energy in MeV of particulate radioactive emissions per disintegration of the parent in a radionuclide chain including alphas, betas, fission product and recoil nuclei
- i case number
- K a characteristic parameter (corresponding to a designated level of cancer risk) of the threedimensional lognormal, dose-rate/timeresponse function of eqn (1); its dimensions

- are the (1 S) power of time and S power of cumulative dose
- K_m the value of the parameter K for which the risk is 0.5 (the median risk)
- K* reference value of K
- m set of integers used in summation
- n number of cases used in summation
- r the correlation coefficient of a least-squares regression analysis
- Risk the independent probability whose value is between 0 and 1 of an individual succumbing to a specific effect assuming that there are no other possible effects; the independent probability P(t < T) of succumbing at a time, t, earlier than a specified time, T
- RR the interspecies response ratio given as the ratio of the cumulative absorbed dose for a specific tissue of a specified radiation in a given species to the cumulative absorbed dose in the corresponding tissue of the same radiation delivered at the same average dose rate in a reference species yielding the equivalent

†Supported by the Office of Health and Environmental Research of the U.S. Department of Energy under contract EY-76-C-03-0472 with the University of California, Davis, CA 95616.

biological response or analogous cumulative nsk; RR is also equal to the ratio of the respective times required after exposure begins to yield the effect and is equal to the reciprocal of the relative biological sensitivity (RBS)

RBE relative biological effectiveness, the experimentally determined ratio of the cumulative absorbed dose of reference radiation (or baseline irradiation pattern) to the cumulative absorbed dose of a radiation (or irradiation pattern) in question required to produce an identical level of biological response (during an identical period of time and other conditions being equal) in a particular experiment. organism or ussue; the ratio of the average dose rate to a chosen tissue leading to a particular biological endpoint at a given time for a reference radiation to the average dose rate to the same tissue leading to the same endpoint at the same time for a specified radiation

- S the negative slope parameter of the threedimensional function (eqn 3) that characterizes the slope of the two-dimensional logarithmic dose-rate/time-response line (eqn 2) for a designated level of risk
- S* reference value of S
- SE the standard error associated with an estimate of a mean value
 - t the time that elapses between beginning of exposure and the observed response
- t_L the approximate median normal lifespan of unexposed individuals measured from the average time of initial exposure for exposed individuals
- $Z = (x \bar{x}) \cdot \sigma$, the standardized normal deviate of a Gaussian distribution given by the ratio with respect to standard deviation of the difference between a given value and the mean η the reciprocal of S
- η^* reciprocal of reference value S^*
- σ_r the geometric standard deviation of a lognormal dose-rate time-response function describing the distribution of times to death (or K values at different risk levels); the antilogarithm of the logarithmic standard deviation which is the root mean square error of the logarithms of times to death with respect to fitted eqn (2)

INTRODUCTION

THE RELATIVELY long-lived bone-seeking radionuclides including radioisotopes of the actinide elements may lead to the long-term chronic

alpha-particle irradiation of bone if deposited in the skeleton of an exposed individual. Boneforming and bone-remodeling cells may be irradiated to various degrees depending upon the characteristics of the radionuclides, including types of emissions, radioactive decay rate, and patterns of deposition and retention in bone. Irradiation of bone cells may occur at relatively high dose rates in occupational exposures and at relatively low dose rates due to environmental exposures. Such irradiation may lead to malignant bone tumors, particularly osteosarcoma. Several bone-seeking radionuclides have been subject to experimental studies using laboratory animals, including naturally occurring 226Ra. 228 Ra and 228 Th and nuclear reactor-produced 238Pu, 239Pu, 241Am, 249Cf, 252Cf and 253Es.

Comparisons of experiments with laboratory animals to human responses to bone-seeking radionuclides is based principally on the accidental and therapeutic exposure of people to ²²⁶Ra and ²²⁸Ra, particularly in the case of those women who accidentally ingested ²²⁶Ra during the painting of luminous dials on clocks, watches and other instruments earlier in the twentieth century and those people who were given dosages of ²²⁶Ra for medical purposes (Ev74). Studies of these cases have been the basis of standards for other internally deposited radionuclides in people and for scaling radiation risks from laboratory animal results to people (Ra80).

The modern nuclear industry involves the production and use of several bone-seeking actinide radionuclides, particularly 238Pu, 239Pu and ²⁴¹Am. The possibility of both occupational and environmental exposure of people to these radionuclides has already been realized in accidental releases and worldwide fallout. For example, the average person in the United States is known to have a 29Pu skeletal burden of about 1 pCi (Mc81). Other radionuclides with nuclear industry applications include the californium isotopes 249Cf and 252Cf as well as the more unusual 253 Es. The advent of the thorium fuel cycle has increased the potential interest of the natural thorium radionuclides, including ²²⁸Th. These radionuclides together with their respective decay products all result in alphaparticle irradiation of bone. Hence the various radionuclides compared in this study include a spectrum of materials of both practical and theoretical interest. The principal characteristics of these nuclides are summarized in Table 1.

Raabe et al. (Ra80; Ra81a; Ra81b) have shown the usefulness of describing the bone tumor dose-response relationship for ²²⁶Ra in beagles as a three-dimensional lognormal response surface in which the coordinates of the response surface are natural logarithms of average skeletal dose rate from the irradiation. logarithm of time to death after beginning of exposure, and risk. They further applied the same model to the available human data and found a plausible parallel relationship displayed by a response ratio (RR) of 3.6 such that the

time to death at a given dose rate (or ²²⁶Ra bone concentration) was found to be 3.6 times longer for people than for beagles. People were thusly found to be only 0.28 times as sensitive to ²²⁶Ra bone irradiation as beagles and this factor was called the relative biological sensitivity (RBS). They also showed that RR was 10 for people relative to mice with an RBS of 0.1 so that people appear to be only 0.1 as sensitive to ²²⁶Ra in bone as mice. These results provide a basis for scaling between laboratory animal species and man in the case of carcinogenic dose-rate/time-response relationships.

The purpose of this current evaluation is to compare the response relationships for bone

Table 1. Properties of selected bone-seeking radionuclides including physical half-life $(T_{1,2})$, alpha energy (Q_s) , beta energy (Q_s) , fission fragment energy (Q_g) and average total energy (E) per distintegration of parent (from Le 67 and Ho 72)

Nuc 1 1de	Daughter	T1/2	Og (Mev)	Q _B (Mev)	Q44 (Mev)	E (Mev)
226a. 88		1602 y	4.77	-	-	4.86
	222=n + progeny	(3.8 d)	19.16	0.86	•	20.36 R(t
2252.		5.75 y	-	0.04	•	0.94
38	2234 _C 87	6.1 h	-	0.36	-	0.36
	222*h	1.91 y	5.40	-	-	5.52
	22.4.a 55	3.64 d	5.67	-	-	5.79
	227an + progeny	(10.6 h)	20.87	0.62	•	21.90 P(t
?392 _u 94	23:	87.75 y	5.49	-	•	5.59
39pu 94	235 ₁ , 92	24,400 y	5.15	•	-	5.24
241 An 95	237 _{mp} 93	458 y	5.49	•	•	5.44
249c1 98	94 24.2 ^{Cu}	360 y	5.76	•	-	6.30
25201 99	2455m 96	2.65 y	5.93	- ,	5.58	11.60
?53 _{E 5}		20.5 d	6.63	•	-	6.75
77	Stěšř	314 d	•	0.04	-	0.04

^{*}P(t) is ratio of radon daughter to racium parent activity (1176)

cancer in beagles for 226Ra and other long-lived alpha-emitting bone-seeking radionuclides to provide estimates of the relative biological effectiveness (RBE). These RBE values with respect to 226 Ra for borze cancer in beagles can be multiplied by the respective average dose rates to yield the equivalent 226Ra dose rate to bone and then scaled to people using the appropriate response ratio. These results can then be used to estimate the risks associated with human exposures to these radionuclides including those permitted by existing occupational exposure standards. Average gravimetric dose rates to the skeleton are used rather than calculated dose rates to cells at bone surfaces, since these calculations are not certain. The observed RBE values from average doses should be indicative of the relative irradiation of the sensitive cells of the skeleton which will prove useful in estimating the effective doses to bone surfaces.

METHODS

Analysis

To evaluate the three-dimensional doserate time-response relationships for a variety of sets of experimental data involving exposures of beagles, a two-dimensional graphical presentation representing the three-dimensional phenomena was prepared as described by Raabe et al. (Ra80). This procedure involved coding each beagle succumbing to bone cancer during lifetime studies as a separate datum plotted with respect to logarithmic coordinates of elapsed time from beginning of exposure to death and average dose rate to skeleton, \bar{D} , during that exposure time (sie Appendix for nomenclature).

The lognormal model (Ra80; Ra81b) involves a basic dose-rate/time-response relationship given by

$$t = K\vec{D}^{-S}, \tag{1}$$

where t is the elapsed time to death after initial exposure associated with the appropriate value of the parameter K, and S is a constant. This function in logarithmic coordinates is given by:

$$\ln t = \ln E - 3 \ln \bar{D}, \qquad (2)$$

where In is the natural logarithm. This linear and the risk can be accurately approximated

function is fit by least-squares regression analysis which provides maximum likelihood estimators of mean values of ln K and S if the errors associated with logarithmic data points are normally distributed. Since each datum can be viewed as representing a separate estimate of In K if S is known, the resulting fitted line becomes a dose-rate/time-response plot with the chosen value of S obtained by the regression and the fitted value of ln K defining the median of a three-dimensional lognormal cumulative dose-rate/time-response surface such that

$$\ln t = \ln K_m + Z \ln \sigma_t - S \ln \bar{D}, \qquad (3)$$

where In is the natural logarithm, t is the time to death, K_m is the fitted median risk value of K and $\ln K = \ln K_m + Z \ln \sigma_{\epsilon} (K = K_m \sigma_{\epsilon}^2)$. Z is the standardized normal deviate equal to zero at the median, σ_{r} is the geometric standard deviation of K (or regressed t) values, S is the negative slope parameter, and \bar{D} is the average dose rate (Ra81b). The risk (indicated by Z for a cumulative normal distribution) is the independent probability (value between 0 and 1) of an individual succumbing to bone cancer assuming there are no other possible effects; it is equivalent to the cumulative incidence rate used by Rosenblatt et al. (Ro71). This relationship describes times to death that are lognormally distributed with geometric standard deviation. σ_{\bullet} , for a given dose rate, as well as dose rates that are lognormally distributed with geometric standard deviation σ_r " (where η is the reciprocal of S) for a given elapsed time.

After eqn (2) was fit by linear least-squares to the selected n cases of bone cancer to obtain estimates of S and $\ln K_{-}$, the geometric standard deviation of K (or time values about the fitted function) was calculated using each i case by:

$$(\ln \sigma_s)^2 = \frac{1}{n} \sum_{i=1}^n (\ln t_i - \ln K_m + S \ln \bar{D}_i)^2.$$
 (4)

Then the standardized normal deviate is given

$$Z = (\ln t - \ln K_{-} + S \ln \bar{D}) / \ln \sigma, \qquad (5)$$

using a standard algorithm for the area under a portion of a normal distribution (Ab64):

RISK = 0.5 +
$$\frac{1}{\sqrt{2\pi}} \sum_{m=0}^{\infty} \frac{(-1)^m Z^{(2m+1)}}{(2m+1)(2^m)m!}$$
, (6)

where the m values are integers whose values become large enough to yield the desired small error. Equations (5) and (6) provide a predictive model of risks with time given the dose rate and values for the parameters K_m . S and σ_r .

The use of individual observations of tumor death times does involve a possibility of bias due to competing risks at high dose rates (where other risks are apparent) and low dose rates (where aging deaths occur). Those few bone cancer cases in these two regions were not used in fitting the response functions. As discussed by Raabe et al. (Ra83), it is inherent in this model that all exposed individuals will eventually succumb to bone cancer (risk = 1) given enough time in the absence of competing risks. The exact percentage of bone cancer cases depends upon the nature of competing risks. It is the underlying independent risk distribution that was studied here.

Relative biological effectiveness (RBE)

The relative biological effectiveness (RBE) is given by the ratio of the cumulative dose of reference radiation to the cumulative dose of a given radiation yielding essentially the same response. Since time to effect must be the same for both the reference radiation and the one being tested for responses to be equivalent, the RBE is the ratio of the average reference radiation dose rate leading to a particular biological endpoint at a given time to the average dose rate leading to the same endpoint at the same time for a specified radiation (Ra81b). Hence, if the skeletal irradiation from ²²⁶Ra yields a given level of risk at a time to death. 1, with average skeletal dose rate from ²²⁶Ra and progeny given by:

$$\bar{D}_{Ra} = \left(\frac{K^{\bullet}}{t}\right)^{n^{\bullet}} \tag{7}$$

and if another skeletal irradiation pattern from another radionuclide in bone has a response at

the same level of risk and time given by:

$$\bar{D}_{\text{other}} = \left(\frac{\dot{K}}{t}\right)^{\eta},\tag{8}$$

then the RBE is given by

$$RBE = \frac{t\bar{D}_{Ra}}{t\bar{D}_{other}} = \frac{(K^{\bullet})^{r^{\bullet}}}{(K)^{n}} t^{n-n^{\bullet}}, \qquad (9)$$

where η is the reciprocal of S and η^* is the reciprocal of S^* . If $S = S^*$ then the RBE is the same for every post-exposure time period with

$$RBE = \left(\frac{K^*}{K}\right)^n. \tag{10}$$

Usually the K and K^* are chosen for the median risk (Z = 0 in eqn 3) for calculation of the RBE.

Sources of data

The compared cases of bone cancer induced in beagles by 226Ra and the other bone-seeking actinides were obtained from progress reports published by three laboratories sponsored by the U.S. Department of Energy in which carefully controlled lifetime studies with purebred beagles have been conducted (Bo80; In81; Rad80). Analyses were performed for deaths from bone cancer or for individuals terminated from the studies due to imminent death from bone cancer. These data include 123 cases of bone cancer in beagles from skeletally deposited 226Ra given as repeated intravenous injections at the University of California, Davis, Laboratory for Energy-Related Health Research; 56 cases for skeletally deposited 234Pu subsequent to inhalation exposure at the Lovelace Inhalation Toxicology Research Institute, Albuquerque, NM; and 41 cases for ²²⁸Ra; 40 cases for ²²⁸Ra; 44 cases for ²²⁸Th; 58 cases for ²³⁹Pu; 29 cases for ²³⁰Ra; ²⁴¹Am; 10 cases for ²⁴⁶Cf; 6 cases for ²⁵²Cf; and l case for ²⁵³Es—each given as a single intravenous injection of one radionuclide at the Radiobiology Laboratory of the University of Utah, Salt Lake City, UT. Of these 408 cases of bone tumors, all but 13 were described as osteogenic sarcoma. Although the diagnoses as reported in these progress reports must be considered tentative, the general analysis performed

herein is designed to clarify the overall relationships and should not be sensitive to small variations.

In these studies, irradiation of the bone begins with the initial administration and continues for the life of the beagle as determined by the skeletal retention of the given radionuclide and the bone mass. The administration of radionuclides by discrete dosage levels (µCi/kg) does not result in identical skeletal dose rates for all dogs in a given dosage level because of differences in growth and retention among individuals so that each beagle should be separately evaluated as much as possible with respect to dosimetry. A threefold difference in lifetime average dose rate appears possible within a single dosage group. Where whole-body counting was not performed, greater dosimetric uncertainty should be expected. Doses were calculated by the various laboratories by summing all particulate radiation energies including appropriate alpha, beta, fission product and recoil nuclei energies (Table 1).

To determine the average radiation dose rate received by beagle bone during an extended period of exposure, the skeletal mass must be known. In the Davis studies the average beagle skeleton weight was assumed to be 8.4% of the body weight up to 540 days of age and unchanging thereafter. The Utah and Lovelace studies made similar assumptions but Utah assumed that the beagle skeleton was 7.5% of the young adult body weight and Lovelace assumed 10% of the body weight. Garsd et al. (Ga81) described the study of beagle skeletal growth at Davis that showed the wet skeleton of a 540-day-old beagle ranges to vary from 7.0% to 9.8% of the body weight with an average of 8.4% (a coefficient of variation of about 6%). To reconcile the different skeletal masses used at the three laboratories, and make the skeletal dose rates comparable, all the reported doses were corrected for an assumed skeletal weight of 8.4% of the young adult body weight. The Utah doses were multiplied by 0.89, the Lovelace dbses by 1119, and the Davis doses remained runch waged.

In the Davis study, 243 young adult beagles comprising both saxes were administered eight fortnightly intravenous injections in six dosage groups of 226 Ra in 9.1 to nitric acid in saline

beginning at 435 days of age and ending with the last injection at 540 days of age. The exposure starting time was taken as the midpoint of this injection period. A total of 78 controls were concurrently injected with equivalent volumes of the 0.1 N nitric acid in saline but without 226Ra. The radium bone burdens were measured by in vivo external counting for each dog throughout its life so that absorbed radiation dose rates and cumulative doses could be estimated for each individual using the appropriate calculated skeletal mass (Ra81a). Details of dosimetry and overall responses have been given by Raabe et al. (Ra81a). Dose response relationships as described by eqns (1), (2) and (3) have been shown to well represent the data (Ra80; Ra81b). The 123 bone cancer cases (all but three being osteogenic sarcoma) provide the largest cohort of cases available in any one study with dogs, and the basis of comparisons of other radiation-induced skeletal carcinogenesis.

The Lovelace study involved the inhalation exposure of 144 beagles varying from 12 to 14 months of age to two sizes of respirable aerosols of 238PuO, as described by Hahn et al. (Ha81). An additional 24 unexposed beagles were assigned as controls. Because of the fragmentation of the 214PuO particles in the lungs of the beagles after inhalation deposition, 234Pu was slowly translocated via the blood to liver and skeleton. The result was that 23Pu exposure of the skeleton involved very little accumulated radiation dose prior to 100 days post-exposure as described by Hahn et al. (Ha81). However, the observed half-time of the lung burden of ²¹⁴Pu was reported to be somewhat greater than 100 days so that the time average burden of ²³⁸Pu in the skeleton was about equal to that of the lung and the gravimetric cumulative radiation dose to the skeleton reached about onefifth of the dose to the lung by 1600 days after exposure (Ha81). Since it was not possible to measure the 234Pu bone burdens by in vivo counting, the measured initial and final lung burdens were used by Hahn et al. (Ha81) with separately determined metabolic models to calculate the skeletal doses (In81). No correction to time to death was made for delayed transport to bone in this analysis.

The Utah lifetime studies with beagles of the

effects of 226Ra, 228Ra, 228Th, 239Pu, 241Am, 249Cf 252Cf and 253Es in bone all followed the same basic experimental design as described by Dougherty et al. (Do62), involving a single intraveneous injection at about 1-2 yr of age. Most exposures were at between 460 and 600 days of age, although a few exposures occurred at later than 2 yr of age. Separate comparative studies, not considered herein, were also conducted at Utah using young dogs and older dogs for evaluation of changing radiation sensitivity with age. Typically, the single injection (8 to 10 ml) was given via the cephalic vein with the chosen radionuclide in a citric acid-sodium citrate buffer solution at pH about 3.5 so that polymerization was avoided. Several dosage levels were used, described by microcurie injected per kilogram body weight at time of injection. For lifetime studies a total of 104 beagles was exposed to 226Ra in seven dosage groups, 74 to 228Ra (which was mixed with small amounts of ²²⁸Th) in seven dosage groups (a few individuals receiving considerable 228 Th with the 228 Ra; L170a), 78 to 23 Th in eight dosage groups (St81), 232 to ²³⁹Pu in 10 dosage groups (Ma76), 116 to ²⁴¹Am in eight dosage groups (L170b), 30 to 24°Cf, and 30 to 252Cf, each in five dosage groups, and 67 to 253 Es in two dosage groups. Dosimetry was based on in vivo counting of individual dogs exposed to 226Ra, 228Ra, 241Am. ²⁴⁰Cf, ²⁵²Cf and ²⁵³Es, but was based on model retention equations for 239Th and 239Pu (L170a). A total of 130 beagles were injected with nonradioactive citrate solutions as controls in conjunction with these various studies.

Among the studies used for the analyses of bone cancer in beagles at the three laboratories there were thus a total of 232 unexposed dogs on lifetime studies as controls. Among these unexposed control dogs only one case of osteosarcoma has been reported. About 25% of these controls are either still alive or their causes of death have not yet been reported, but the incidence of bone cancer among unexposed beagles is probably less than 0.5% and may be as small as 0.01% (Ma69). The use of individual bone cancer cases herein to estimate the cumulative risk presumes all observed cases are in fact radiation induced. Cases occurring near the end of life span were not used to avoid distortion of the dose-response function caused by competing

risks; natural bone cancers, if present, would likely be among these censored cases.

RESULTS

The results of fitting eqn (2) to the data for these sets of bone cancer cases in beagles are summarized in Table 2. Overall, the negative slope parameter S was similar for all of the radionuclides with an average of 0.29 (0.01 SE). Dose-rate/time-response functions with S =0.29 were also fit to these data and are given in Table 3. The 226Ra results at Utah correspond almost precisely with those at Davis with only a 3% difference between the fitted values of K_{-} and negative slope S. Figure 1 illustrates the combined 226Ra data from Utah and Davis and the response function given by Raabe et al. (Ra80; Ra81b). The three-dimensional lognormal dose-rate/time-response surface represented by these data was reconstructed from eqns (3) and (6) as shown in Fig. 2.

The observed response relationships for bone cancer in beagles from ²⁴¹Am, ²⁴⁹Cf, ²⁵²Cf and ²⁵³Es are all similar as shown in Fig. 3 with the median function for ²⁴¹Am from Table 3. Those for ²⁵⁸Pu and ²⁵⁹Pu were somewhat different from each other as shown in Fig. 4 with the fitted median functions from Table 3. The ²⁵⁹Pu results for dose rates larger than 2 rad/day yielded essentially the same time to death, so that those six cases above 2 rad/day were not used in obtaining the fitted lognormal response function, because they do not fit eqn (2).

The results for ²²⁸Th and ²²⁸Ra are shown in Fig. 5 with the median response functions from Table 2. The fact that some ²²⁸Ra-injected beagles also received significant dosages of ²²⁸Th mixed with the ²²⁸Ra was not apparent from these results. Dogs receiving ²²⁹Th with ²²⁸Ra were not distinguishable from the other ²²⁸Ra dogs on the dose-rate/time-response plot.

The observed skeletal bone tumor doserate/time-response functions for these nine bone-seeking radionuclide chains involving alpha irradiation of bone are basically similar with average negative slope S of 0.29 (0.01 SE). The distribution of bone cancer cases about their respective median values of $K(K_m)$ in Table 2) have about the same logarithmic variance ($\sigma_r = 1.17$ with 0.01 SE) for the radionuclides. Hence these response functions are all surfaces

Table 2. Fitted parameters of the lognormal dose-rate; time-response surface for radiationinduced bone cancer in beagles for selected bone-seeking radionuclides (eqns 2 and 3) where S is the negative slope (with standard error. SE) and o, is the geometric standard deviation (with the fitted S) of K values about the median K_m (with geometric standard error, GSE) for n cases of bone cancer deaths (with the correlation coefficient, r)

NurJide*	K™ (@ZE)	\$ (3E)	=g (SE)	n	r	Dosimetry
226 _{Ra} (D)	2464 (1.02)	0.29 (0.01)	1.17	115	0.93	<u> </u>
226 _{Ra} (U)	2441 (1.03)	0.30 (0.02)	1.15	39	0.95	۳
228ea (U)†	[1793 (1.03)]*	[0.35 (0.03)	ינָסג.ויַ יוַ	36	0.90	μ
228Th (U)	1188 (1.03)	0.35 (0.02)	1.16	39	0.96	c
238 pu (l)	1171 (1.07)	0.25 (0.05)	1.13	50	0.62	c
239pu (L ⁱ)	1343 (1.04)	0.27 (0.02)	1.18	44	0.91	Ċ
241 Am (U)	1450 (1.06)	0.29 (0.04)	1.19	28	0.81	W
249,252c <i>f/</i> 253Es (U) Aver a ges	1399 (1.06)	0.31 (0.05) 0.29 (0.01)	· ——	17 01)	0.82	м

^{*(}D) = Davis. (L) = Lovelace. (U) = Utah

Table 3. Fitted parameters of the lognormal dose-rate/time-response surface for radiationinduced bone cancer (eqns 2 and 3) in beagles with fixed negative slope S=0.29, where σ_s is the geometric standard deviation of K values about the median K, (with geometric standard error, GSE) for n cases of bone cancer. The correlation coefficient, r, and calculated relative biological effectiveness (RBE) relative to Daxis Ra results (D) are also given

Muci 1de*	Km (655)	- 5	n	r	R85
226Ra (D)	2464 (1.02)	:.17	115	C.92	1.0
226 _{Ra} (U)	2423 (1.02)	1.15	39	0.93	1.1
228 _{Ra} (U)†	[1794 (1.03)]*	[1.20]*	36	0.89	3.0
228Th (U)	1240 (1.03)	1.19	39	0.94	10.7
238pu (L)	1113 (1.02)	1.19	50	0.61	15.5
239Pu (U)	1305 (1.02)	1.18	44	0.91	9.0
241Am (U)	1440 (1.03)	1.19	30	0.83	6.4
249,252 _{Cf/} 253 _{Es} (U)	1428 (1.03)	1.12	17	0.82	6.6

g(p) = iDwis, (L) = Lovelace, (U) = impeh 1228Ra mixed with small amounts of 2227 ; some individuals were injected with a solution in which 2287h contributed lift of the total disintegration rate.

^{*(0) =} Davis, (L) = Lovelace, (2) = Itan **C = doses calculated based on average retention equations for separately studied dogs, # = doses evaluated based upon in vivo measurements of body and skeletal retention on an individual dog basis *T228Ra mixed with different levels of 225%, values not used for averages

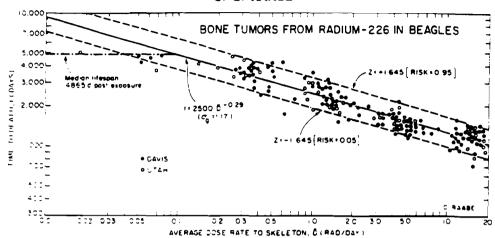


Fig. 1. Summary of bone cancer cases in beagles associated with exposure to 20 Ra at Davis and Utah showing the lognormal dose-rate-time-response model proposed by Raabe et al. (Ra80; Ra81b) for the median risk (Z=0), at $t=2500D^{-0.29}$ (solid line) and the 5 and 95% risk levels at $Z=\pm 1.645$ (dashed lines) for $\sigma_t=1.17$, where Z is the standardized normal deviate, plotted as logarithm of elapsed time (t) to death from bone cancer after initial exposure versus logarithm of average dose rate (D) to skeleton.

BONE TUMORS FROM RADIUM-226 IN DOGS

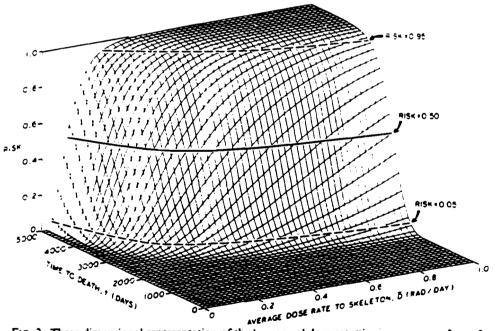


Fig. 2. Three-dimensional representation of the lognormal dose-rate/time-response surface of eqn (3) (for median $K_m = 2500$, S = 0.29, and $\sigma_c = 1.17$ illustrated in two-dimension in Fig. 1) for the risk of bone cancer from ²⁵⁸Ra in beagles plotted as risk at various times to death and average dose rates to skeleton. All dose rates result in risk = 1 given enough time. Multiplying the time by the response ratio (RR) for people = 3.6 (Ra80; Ra81b) yields the equivalent three-dimensional risk model for bone cancer for people.

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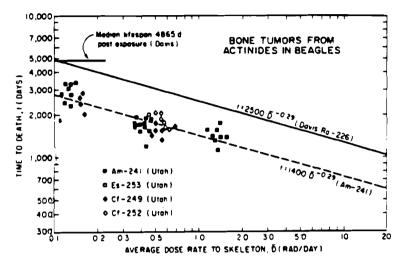


Fig. 3. Two-dimensional comparison of the fitted median (Z=0) response relationships for beagles that died of primary bone cancer from exposures to ²⁴¹Am, ²⁴⁹Cf, ²⁵²Cf, and ²⁵³Es and the median (Z=0) response function for ²²⁶Ra from Fig. 1, plotted as logarithm of time (t) from initial exposure to death vs the logarithm of average skeletal dose rate (D).

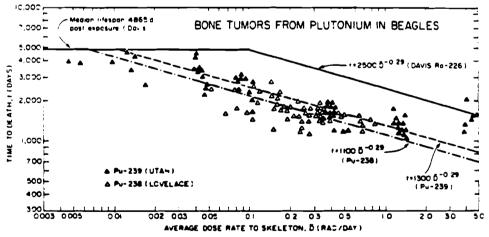


Fig. 4. Two-dimensional comparison of the fitted median (Z=0) response relationships for beagles that died of primary bone cancer from exposures to ²³⁹Pu and ²³⁸Pu and the median (Z=0) response function for ²⁵⁶Ra from Fig. 1, plotted as logarithm of time (t) from initial exposure to death vs the logarithm of average skeletal dose rate (D).

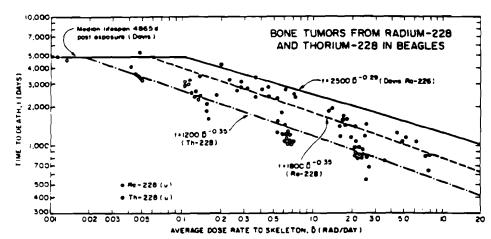


Fig. 5. Two-dimensional comparison of the median (Z=0) fitted response relationships for beagles that died of primary bone cancer from exposures to ²²⁸Ra and ²²⁸Th and the median (Z=0) response function for ²³⁶Ra from Fig. 1, plotted as logarithm of time (I) from initial exposure to death vs the logarithm of average skeletal dose rate (D).

similar to the three-dimensional relationship shown in Fig. 2 displaced according to their respective differences in K_m . The relative biological effectiveness (RBE) values were calculated as given by eqn (10) using the ²²⁶Ra results as the reference radiation dose pattern. These RBE values are also given in Table 3.

DISCUSSION

Dose-response functions

The use of lognormal dose-response relationships in describing such data has been well established in toxicology (Li49) and radiation biology (St57). Also, the apparent linearity in logarithmic coordinates of the variation of time to effect with dose rate has been previously described for both chemical and radiation carcinogenesis by Druckrey (Dr67) and Albert and Altschuler (Al73). Raabe et al. (Ra81b; Ra83) further systematized this approach with emphasis on the underlying three-dimensional response surface that describes the risk distribution with respect to dose rate and time. This report further demonstrates the three-dimensional surface and its usefulness in comparing responses from different radionuclides.

The overall remarkable similarity of the response patterns for these nine bone-seeking radionuclides (with progeny) using these methods

of evaluating the data is apparent from the results. The negative slopes. S. are all similar, the distribution of cases about the median lines have nearly identical variances. Interpretation of the results reduces to consideration of the respective apparent relative biological effectiveness. The close agreement between the Utah and Davis ²²⁶Ra studies is remarkable considering the differences in exposure patterns (single injection vs multiple injections), laboratory management and dog genetic history.

Marshall and Groer (Ma77) developed a mathematical three-step cellular model of bone cancer induction from ²²⁶Ra involving initiation, promotion, and cell killing. They used it to interpret the "Ra bone cancer data in the Utah beagles and in the available human data. Their model involved a type of three-dimensional analysis with data arrays of dosage level, time and cancer yield. Radiation dose rates to the endosteal cells were estimated and used for dose calculations. However, although they removed losses from competing risk retrospectively, they did not correct the cancer yield values for prospective competing risks (such as spontaneous deaths from aging or from other radiolytic effects). Their model was fit by the minimum chi-square method. Their results yielded several conclusions that conflict with the findings described herein. These conflicts include their conclusion that tumor rate reaches a plateau at high doses and that a given cumulative dose "procaces a single tumor rate...no matter what patturn of dose rates and times tesulted in the dose". In fact the time to effect is crucial and the cumulative dose is a poor indicator of the tumor rate. Cumulative dose has been shown to be an inappropriate basis for ²²⁶Ra induced bone cancer risk estimation (Ra81b; Ra83). The incidence plateaus that they observed at high doses were caused by competing risks.

Mays and Lloyd (Ma72) fit linear functions to two-dimensional plots of uncorrected bone cancer incidence vs cumulative dose for beagle. human and rodent data involving 226Ra, 236Th and 239Pu and found reasonable good correlation. However, since their incidence data were not corrected for completing risks, the relationship of these results to corrected cumulative incidence rates is not clear. Rowland et al. (Ro83) studied the human 226Ra bone cancer data, but also neglected to correct for competing risks so that their results also reflected an amaigamation of the various risks with a reduction of bone cancer risk implied at higher doses due to deaths associated with carcinoma of the nasal sinuses, and other detrimental radiogenic effects. Rosenblatt et al. (Ro71) and Goldman et al. (Go73) used a rigorous lifetable approach to evaluating the risk function (cumulative incidence rate) for the Utah 226Ra beagle data adapting the method of Cutler and Ederer (Cu58). They fit their results adequately to logistic functions to form a three-dimensional surface. However, even though the three main dosage groups had risk that achieved 100% at later times, they chose to truncate the results producing a lower maximum risk at lower dosage levels to simulate the incomplete cumulative incidence rate data at those lower levels. Otherwise, their three-dimensional model would have been similar in essential features to the lognormal model.

The individual case approach used in this report avoids the problem of correcting for compating risk by presuming that the overall distribution of cases in time will not be markedly changed by a few losses to other efficies. However, the cases occurring in region of disserate for which competing risks are substan-

tial were not used in the analysis. A major shortcoming of this approach as it stands is the absence of a clear method for weighting the points in the fitting process to adjust for small biases associated with losses to competing risks.

If the time to neoplastic response is proportional to the average distance between radiation events for alpha irradiation as suggested by Jones and Grendon (Jo75), then the true negative slope. S. for the logarithmic response functions would be exactly one-third, since the average chord between events is proportional to the cube root of the concentration of events given by the dose rate. The observed values of S for ²²⁸Ra and ²³⁸Th were close to one-third (Table 2). In fact, the observed average value of S of about 0.29 observed in these regression analyses may be smaller than the true value because the independent variable, dose rate, is itself a variate having a statistical uncertainly.

For example, the 226 Ra dosimetry assumes that all beagles have skeleton weight 8.4° of body mass at 540 days of age. The actual distribution of the skeletal mass has about a 6° coefficient of variation (Ga81), so that the dose rates calculated have a logarithmic variance, $\sigma^2_{\text{in } B}$, of about $\ln^2(1.06)$. Kendall and Stuart (Ke79) treat the statistical problem of statistical uncertainty in the independent variable and provide an improved estimate of the negative slope given by

$$\hat{S} = S / \left(1 - \frac{\sigma^2_{\text{hd}}}{\ln^2 \sigma_{\text{g}}} \right), \tag{11}$$

where $\ln^2 \sigma_t$ is the observed variance of the $\ln t$ values about the fitted function (eqn 4). The resulting improved estimate of the negative slope S=0.335 for the 226 Ra data is very close to one-third. Since the 226 Ra data are clearly the most reliable of all those presented, this result suggests that the underlying true negative slope for all these radionuclide logarithmic doserate time-response relationships may in fact be one-third, as suggested by the average chord model (Jo75). Table 4 and Fig. 6 show the revised median results when a logarithmic function with S=1/3 is assumed.

Relative biological effectiveness

The observed differences m relative biological

Table 4. Fitted parameters of the lognormal dose-rate/time-response surface for radiation-induced bone cancer (eqns 2 and 3) in beagles with fixed negative slope, S, equal to one-third where σ_t is the geometric standard deviation of K values about the median K_m (with geometric standard error, GSE), for n cases of bone cancer. The correlation coefficient, r, and calculated relative biological effectiveness (RBE) relative to Davis 226 Ra results (D) are also given

					<u> </u>		
Nucl ide*	Km (GSE)	°g	n	r	RBE		
276aa (D)	2575 (1.02)	1.18	115	0.92	1.0		
226Ra (U)	2515 (1.02)	1.16	39	0.94	1.1		
228 _{Ra} (U)†	[1793 (1.03)]†	[1.20]†	36	0.90	3.0		
228Th (U)	1200 (1.03)	1.16	39	0.96	9.9		
233pu (L)	1052 (1.03)	1.19	50	0.58	14.7		
239pu (U)	1226 (1.03)	1.20	44	0.88	9.3		
241Am (U)	1382 (1.03)	1.20	30	0.81	6.6		
249,252 <u>cf/</u> 253 <u>5</u> s (U)	1373 (1.03)	1.12	17	0.82	6.6		

 $[\]tau(0)$ = Davis, (i) = Lovelace, (U) = Utah 1228Ra mixed with small amounts of 228Th; some individuals given 152 226Th by activity dosage.

effectiveness can be interpreted as differences in the temporal and spatial pattern of absorbed dose to the sensitive living cells associated with bone surfaces in the skeleton (Ma73). This may be directly related to differences in distribution patterns. Beddoe and Spiers (Be79) provide calculations of the relative cellular surface doses for bone "volume-seeking" radionuclides such as ²²⁶Ra and for "surface-seeking" radionuclides such as ²³⁹Pu. They found the ratio of cellular doses between ²³⁹Pu and ²²⁶Ra to be 6.2 for beagles and 7.0 for man for trabecular (cancel-

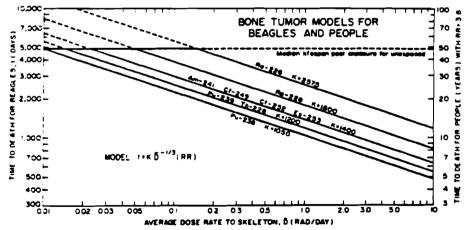


Fig. 6. Two-dimensional representation of theoretical dose-rate/time-response models shown at the median (Z = 0; risk = 0.5) for beagles (RR = 1) and people (RR = 3.6) for primary bone cancer from exposure to nine bone-seeking radionuclides assuming the time (t) to death from initial exposure is inversely proportional to the cube root of the average skeletal dose rate (D).

lous) bone, compared to 49.2 for beagles and 25.2 for man for cortical (compact) bone. Although most of bone is cortical (about 80%), most cells at risk and most deposited radionuclide atoms are in trabizular bone. If it is assumed for beagles that 15% of each of the radionuclides deposits in cortical bone and the remaining 85°, deposits in trabecular bone, then an RBE of about 16.6 would be expected from their calculations for ²³⁹Pu with respect to ²²⁶Ra assuming they behave as ideal surface and volume seekers, respectively. Actually, neither radium nor the actinides will be ideally distributed so that RBE values smaller than 16.6 as observed are consistent with expectations.

The volume-seeker radionuclides are those that chemically incorporate like calcium into the bone but they begin as surface deposits in areas of bone remodeling. The surface seekers are those that associate with tissue at bone surfaces and do not enter into the ordinary chemical processing of bone mineral. For example, Pu(IV) does not form ions at physiological pH (Ra78) and may enter into macrochemical interactions with biological complexing agents including citrate. The in vivo mobilization of these actinides may be a fragmentation process (F177). The relative consistency with time after exposure of the RBE values for each actinide suggests that they continue a cellular association through the life of the beagle.

Two relationships among the observed RBE values are of particular interest. Neither the two radium isotopes nor the two plutonium isotopes demonstrate consistent RBE values. The RBE of ²²⁸Ra was observed to be 3 with respect to ²²⁶Ra, while the RBE of ²³⁸Pu was observed to be 15.5 compared to only 9.0 for ²³⁹Pu. The small difference in irradiation energy for the respective isotope pairs does not appear sufficient to explain these differences. Several possibilities exist; however.

The ²²³Ra is not an alpha emitter and must decay to ²²³Th before any alpha irradiation occurs (Table 1) The ²²⁴Th may become partially associated with surface cells before it decays enhancing its effectiveness. This possibility could explain the RTE of 3.0 observed for ¹²³Ra

The high observed RBE of Pa nompared to 2.4Pu may be related to differences in macro-

chemical form since 238Pu probably entered the blood as ultrafine particles of PuO, smaller than 0.01 µm in dia. (Ra78) while 219Pu was injected as a citrate complex. Enhanced cellular association may be associated with particulate 238Pu. Another possible explanation is related to the protracted nature of the exposure of bone surfaces associated with the inhaled 238PuO2 compared to injected 239Pu citrate. After inhalation of 234 PuO2, plutonium passed from lung to bone via blood over several hundred days so that many more cells on various bone surfaces may be been encountered by the depositing ²³⁸Pu. Either or both of these considerations could explain the higher observed RBE for inhaled ²³⁸Pu compared to injected ²³⁹Pu.

Induction time and latency

As reported by Raabe et al. (Ra80; Ra81b). the time between initiation of exposure and death from bone cancer is longer at lower average dose rates (lower radionuclide bone concentrations) than by higher average dose rates. If there is a minimum latent period associated with the induction of bone cancer, its effect on the dose-rate/time-response relationship was not completely clear. The 219Pu data for dose rates above 2 rad/day suggest a minimum time between exposure and death of about 1000 days, but the 221 Th data show deaths from bone cancer as early as 550 days. It is reasonable to expect that there must be a minimum latent period after induction of bone cancer, and it is therefore probably shorter than about 500 days.

A practical threshold dose or dose rate below which bone cancer deaths are unlikely is suggested at low dose rates for all these radionuclides, just as has been reported for 226Ra (Ra80). This occurs because the elapsed time required to reach an appreciable risk level increases as dose rate (exposure) decreases and may exceed the normal lifespan. As individuals age, they enter the region of increasing risk as shown by increasing t in Figs. 1-6. At high dose rates the region of risk for bone cancer is encountered before the region of risk for natural death, so that premature death from bone cancer is more excobable than death from aging processes. At low dose rates, on the other hand, natural deaths occur before bone tumors develop. The median natural lifespan for unexposed control beagles at Davis is shown for reference as t_L in Fig. 1 and Figs. 3–6. Raabe et al. (Ra80; Ra81b) calculated a practical threshold for ²²⁶Ra-induced bone cancers in beagles using three geometric standard deviations below the median risk at a cumulative dose of about 50 rad at the median lifespan; this would yield a 0.13% risk near the end of natural life. Similar practical threshold values for beagles can be calculated for the other radionuclides by dividing by their respective RBE values (Table 3) to obtain about 5 rad for ²²⁸Th, 3 rad for ²³⁸Pu, 6 rad for ²³⁹Pu, 8 rad for ²⁴¹Am. ²⁴⁹Cf, ²⁵²Cf, or ²⁵³Fs.

Interspecies scaling

To scale the dose-response results to people or other animals, the same dose-rate/time-response relationships derived for beagles (eqn 3) can be applied to other species using the procedure described by Raabe et al. (Ra80; Ra81b). In this approach the relationships are displaced by a species-dependent factor named the response ratio (RR) so that the median value of K for the selected species is given by

$$K_{-} = K_{-}(\text{beagles}) \times RR.$$
 (12)

The values of RR for people and mice for 226Ra

were calculated to be 3.6 and 0.34, respectively. The observed σ_r values for mice and people were larger than for beagles, but this may be due to data uncertainties rather than intrinsic differences in relative variance.

To use the same response ratios for bone tumors from the actinides, RBE values must be the same for these nuclides in the three species. The evidence is limited, but data are available comparing CF, female mice that were injected with either 226Ra bromide or 239Pu citrate in separate experiments (Fi62; Fi69; Ro62; Ro69). The studies by Finkel (Fi62; Fi69) did not involve measurements of bone retention, so dose rates had to be based upon retention assumptions. The 226Ra dose was calculated as reported by Raabe et al. (Ra81) and the 239Pu dose was calculated with the same assumptions. but with the 219Pu retention data for female CF, mice reported by Rosenthal and Lindenbaum (Ro62: Ro69). Functions of the form of ean 2 were fit to the median time of death for each dosage group based upon the calculated average dose rate for the group. This comparison for mice is shown in Fig. 7 in which the median time to death ($\pm 34\%$ range) is plotted vs average skeletal dose rate. The observed σ_r values were 1.2 for ²³⁹Pu and 1.3 for ²⁵⁶Ra. Only the higher dosage groups were used to avoid bias caused by the competing risks at the median lifespan $(t_L = 655d)$. The calculated RBE = 11.4, based

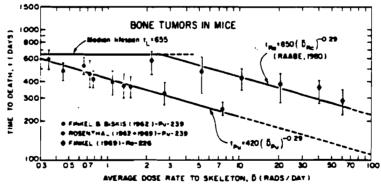


Fig. 7. Two-dimensional presentation of the primary bone tumor deaths at the high dose rates for female CF₁ mice similarly exposed to ²³⁹Pu by Finkel and Biskis (Fi62) and by Rosenthal and Lindenbaum (Ro62; Ro69) and to ²³⁶Ra by Finkel *et al.* (Fi69) showing the response model of median risk with S = 0.29 plotted as logarithm of time (t) to death after initial exposure vs logarithm of average skeletal dose rate (D).

upon the fitted functions. This RBE is not remarkably different from the RBE = 9 for beagles for ²³⁹Pu bone tumors. This suggests the acceptability of using the same response ratios for actinides as observed for ²²⁶Ra along with the RBE values observed in the beagle studies, although the exact RBE values for people are now known.

Hence, the dose-rate/time-response relationship for people for bone tumors from these alpha-emitting radionuclide chains can be obtained from

$$t = (RR)KD^{-5}. (13)$$

where the values of E and S are those obtained for beagles and RR is the appropriate response ratio. On this basis, the time to death cocrdinates of Figs. 2 and 6 can be multiplied by 3.6 to provide the equivalent dose-response relationship for people (as indicated in Fig. 6) or by 0.34 to provide the equivalent results for mice. Raabe et al. (R180) estimated a 226Ra bone cancer practical threshold for people (with $\sigma_r = 1.31$) of 80 rad delivered over 55 yr (9.004 rad day). With the RBE values of Table 5. the corresponding practical threshold values from eqn (13) are therefore about 7 rad for 218Th, 5 rad for 236Pu, 9 rad for 239Pu, and 12 rad for 241Am, 249Cf. 252Cf, or 253Es. At the current accepted maximum bone burdens for occapational exposures (3 rad/yr for radium, 0.6 rad yr for other alpha emitters), the calculated bone cancer risk after 50 yr of exposure using eqns (5) and (6) would be 10^{-1} for 226 Ra, 0.03 for 226Ra, 0.007 for 226Th, 0.03 for 236Pu, 0.303 for ²³⁹Pu, 10⁻³ for ²⁴¹Am, ²⁴⁹Cf, ²⁵²Cf, or ²⁵¹Es, assuming $\sigma_s = 1.2$ for people for all the nuclides and S = 0.29 (Table 3). A skeletal burden of 1 pCi of ²³⁹Pu as is common among the general population due to environmental exposures (Me81) would result in an infinitesimal risk in 70 yr ($< 10^{-32}$).

SUM!SARY

The dose-response relationships of nine bone-seeking radionuclides with progeny) for the production in beagles of primary bone cancer by alpha-particle irradiation follow mathematically similar lognormal dose-rate/time-response relationships with negative slopes of about 0.29

but displaced with respect to 226Ra by relative biological effectiveness that varies from 3.0 for ²²⁸Ra and 6.4 for ²⁴¹Am, ²⁴⁹Cf, ²⁵²Cf and ²⁵³Es to 9.0 for ²³⁹Pu, 10.7 for ²²⁸Th and 15.5 for ²³⁸Pu. A true negative slope of exactly one-third is suggested by the statistical interpretation of the results. All radionuclide exposures showed longer induction periods at lower dose rates. For each radionuclide exposure and species a practical threshold dose or dose rate exists below which no cancers are observed because the time required to reach significant tumor risk exceeds the natural life span. Use of a previously observed response ratio of 3.6 for man allows the prediction of dose-rate time-response relationships for people from these results. It takes 3.6 times longer to manifest bone tumors or develop equivalent risk in people than in beagles at any given dose rate (bone concentration of radionuclides).

Acknowledgment—The author thanks Drs. M. Goldman and S. Book for helpful suggestions. Mr. C. Baty for manuscript preparation. Mr. K. Shiomoto for illustrations, and Mr. V. Pietrzak for assistance in computer programming graphics. This work was supported by the Office of Health and Environmental Research of the U.S. Department of Energy under Contract No. EY-76-C-03-0472 with the University of California, Davis. CA.

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Reprinted from

HEALTH PHYSICS

Official Journal of the Health Physics Society



PERGAMON PRESS

OXFORD . LONDON . NEW YORK . PARIS

THE REMOVAL OF STRONTIUM™ FROM ORGANIC WASTE*†

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(Received 17 December 1962; in revised form 26 March 1963)

Abstract—Continuous production of organic wastes from a large dog colony on a diet containing various amounts of Sr⁹⁰ required the design and construction of a moderate-size waste treatment plant. The contaminated wastes contain in excess of $5 \times 10^{-6} \, \mu \text{c}$ Sr⁹⁰/ml and are produced at approximately 200–500 gal/day. Decontamination depends upon efficient utilization of the principles of primary sedimentation, aeration, chemical clarification and filtration prior to passage of the waste through 5 ft³ of cation exchange resin. The expended resins are disposed of by offsite burial. Treatment of over 115,000 gal of waste has produced final effluents whose average annual concentration does not exceed the current permissible limit for Sr⁹⁰ in drinking water. The treated waste stream is discharged into an underground leaching field. Decontamination factors up to 5×10^6 have been achieved. The current cost of treatment is estimated at less than 15 cents/gal including material, (resin costs 1.2 cents/gal), labor and plant amortization.

INTRODUCTION

In 1955, at the School of Veterinary Medicine of the University of California at Davis, plans were formulated to create a major research facility to study the long-term effects of continual ingestion of Sr⁹⁰ contaminated food by a large colony of beagle dogs. It was immediately obvious that special planning would be necessary to handle the disposal of excreta from these dogs during the Sr⁹⁰ feeding period. The experimental plan entailed feeding Sr⁹⁰ to over 200 dogs from the onset of fetal ossification through weaning (via the dam), and thereafter in the daily ration until 18 months of age. Following the Sr⁰⁰ ingestion period, the dogs are maintained on the same diet (without added Sr⁹⁰) for their life-span in order to observe and evaluare the physiologic and pathologic effects of

long-term Sr⁹⁰ exposure. Through correlation of these results with those obtained from a parallel study on a colony of dogs receiving a comparable body burden of Ra²²⁶ by intravenous injections, and with known Ra²²⁶ effects in humans, extrapolations will be made to possible long-term effects of Sr⁹⁰ ingestion in man.

Seven dose levels were included in the Sr⁹⁰ ingestion phase of the experimental design as

Table 1. Strontium 90 ingestion phase of experimental design

	_		Total	
Dosc level	Number of dogs	Diet (μc Sr ⁹⁰ /g Ca)	mc	% of total
5	35	3.33	179.4	67
4	35	1.11	59.8	22
3	35	0.37	19.9	7
2	35	0.123	6.6	2
1	35	0.021	1.1	711
0.5	40	0.007	0.5	(1)
0	65	0.000	0	
			267.3	

¹¹ Based on a total of 540 meals per dog with an average 5 per cent retention of Sr⁸⁰ fed. (300 g food/dav/dog at approx. 1 per cent calcium.)

[•] Work performed under the auspices of the U.S. Atomic Energy Commission.

[†] Presented in part at the Annual Meeting of the Health Physics Society, June 11-14, 1962, Chicago, Illinois.

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summarized in Table 1. Of the 300 mc of Sr⁹⁰ used in the study, 90 per cent are administered to the two highest levels. Since Sr⁹⁰ is inefficiently absorbed by the animal from the diet, (1) a major fraction (approximately 90-95 per cent) appears in the exercta. The ingestion phase of the experiment extends over a span of several years, since all dogs are not treated simultaneously.

PRELIMINARY INVESTIGATIONS

Laboratory studies were undertaken by the Sanitary Engineering Research Laboratory of the University of California at Berkeley to provide guides for the design of a suitable disposal scheme capable of treating Sr⁹⁰-contaminated organic wastes. Because of the volume of waste to be generated, it was essential that decontamination be sufficient to permit local discharge.

Initially, the composition and volume of the waste had to be estimated. The daily food provided each dog would consist of approximately 300 g, containing 1 per cent calcium, and prescribed amounts of Sr⁹⁰. The amount of drinking water was calculated to be 600 ml (5 meq/l. total hardness). The corresponding amounts of waste material were estimated to be 175 g of solids daily, both feces and uneaten food, and 600 ml of urine. Cage washing appeared to require 2-3 gal of demineralized water for each dog per day. Calculations based on these data provided the estimated characteristics of the waste stream given in Table 2.

Table 2. Estimated waste stream characteristics

Volume 200-500 gal/day Total solids 15.000-21,000 mg/s. Total hardness 25-36 meq/l. Strontium⁹⁰ 0.3-0.5 µc/l.

Preliminary cost estimates indicated that land burial or sea disposal of the entire waste stream would be costly. Both evaporation and ion exchange appeared more attractive from an economic standpoint; however, evaporation posed problems of safe handling, possible air contamination from off gases, and uncertain boiling properties because of the high organic content of the waste. For these reasons it was decided to investigate various treatment possibilities utilizing ion exchange.

Since solids suspended in a liquid passing through an exchange resin column may adversely affect the ion exchange process by blinding resin pores or blocking exchange sites, in addition to the complexing of Sr⁹⁰ into non-exchangeable forms, alternate waste streams were considered:

- (1) Either a combined stream that includes fecal material, excess or spilled food solids, urine and demineralized water:
- (2) or a separated waste liquid stream that includes urine and wash water, and, in addition, a relatively small amount of solid waste washed from the cages.

Collection of solid wastes at the cages for separate disposal would have been required in the case of the second alternative, and laboratory and University Radiological Protection personnel favored the combined system since it appeared to simplify cage cleaning and waste transport.

The feasibility of adopting ion exchange for the treatment of the dog wastes was dependent upon the degree of decontamination obtainable. The unit used to express the degree of decontamination obtained is the Decontamination Factor:

Decontamination Factor (DF) =
Initial Radioactivity Concentration
Final Radioactivity Concentration

Laboratory confirmation of the ability of ion exchange to achieve the required decontamination was necessary. The effect on decontamination of such parameters as flow rate, cation concentration in the influent waste liquid and residence time in the ion exchange column were investigated. The influence of the organic colloidal material on the success of the resin in removing Sr⁹⁰ could be evaluated only by laboratory studies with simulated wastes. Fecal matter and urine from test animals were diluted with appropriate amounts of distilled water and the mixture allowed to digest for 2 months. The supernatant was withdrawn and used in the laboratory study as waste representative of the actual waste stream after primary settling but without additional pretreatment.

The first laboratory experiments consisted of determining the decontamination obtainable by

passing the supernatant from the digested synthetic waste through a cation resin column without pretreatment. (2) Sr⁹⁰ was added to enable measurement of the decontamination factor. The simulated waste contained about 2000 mg/l. non-settleable solids and 1.4 meq/l. total hardness, with a pH of approximately 8.0. The influence of resin residence time of the simulated waste on the decontamination factor is shown in Fig. 1. The resin used in the 1-in. diameter glass columns for all the experiments was a high capacity, strong acid cation exchanger, in the sodium form, commercial grade, 8 per cent cross linkage, 16-50 mesh.

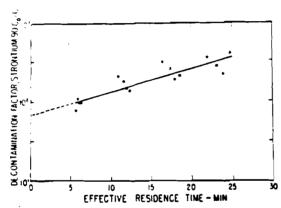


Fig. 1. Decontamination of simulated waste by ion exchange without pretreatment (constant flow rate using variable column length).

The effluent requirements adopted for the laboratory investigation were from the current drinking water radiation guides established by the AEC. This limit would require that a DF of approximately 10⁴ be obtained by treatment of the waste. The laboratory investigation of strontium removal by ion exchange without pretreatment did not provide a sufficiently large DF, therefore additional studies were undertaken to determine the effect of waste pretreatment.

Various pretreatment methods were investigated to improve the decontamination by removing a greater part of the non-settleable solids. The criterion used was maximum clarification without production of excessive sludge. The primary investigation was flocculation with aluminum sulfate or ferric sulfate under different pH conditions, although ancillary studies of

prechlorination, aeration and filtration were also conducted. Ferric sulfate was found to be superior to aluminum sulfate as a coagulating agent. However, higher concentrations of ferric sulfate were required, resulting in greater sludge volumes. Prolonged aeration prior to flocculation reduced the coagulant dosages by about 50 per cent for the same clarification, but the frothing and foaming associated with the aeration process was considered undesirable. Prechlorination and filtration appeared to be of marginal benefit.

The influence of residence time on the effluent concentration of Sr^{90} and Y^{90} in chemically coagulated wastes is shown in Fig. 2. One of the most interesting observations was the passage of appreciable concentrations of Y^{90} through 8 ft of cation exchange column, preceding both calcium and strontium. Since vttrium is trivalent it was evident that the yttrium present in the

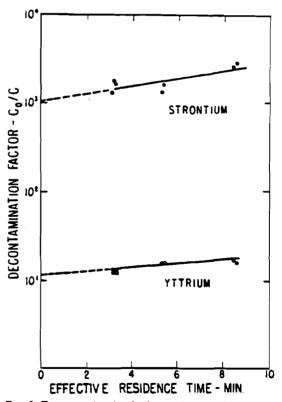


Fig. 2. Decontamination by ion exchange of simulated waste following chemical treatment (constant column length using variable flow rate).

simulated waste was either nonionic or complexed in a form having a low affinity for the cation resin. Fortunately, Y⁹⁰ has only a 65-hr half-life and can be removed from the plant effluent by simple retention.

The pH of the treated waste flowing into the ion exchange column was also found to be of importance. A greater DF was obtained by lowering the pH of the applied liquid to less than 3.5. This apparently minimizes the formation of complexes of strontium and yttrium and thereby increases the probability of their exchange by the resin.

Although strontium is sorbed by ion exchange resins in preference to calcium, the latter serves to reduce the unit capacity of an exchanger for strontium and it was therefore recommended that demineralized water be utilized for the washing of the dog cages.

The laboratory investigations indicated that ion exchange columns would provide Sr⁹⁰ decontamination factors up to 10⁴. However, in order to achieve this level of decontamination reliably, it would be necessary to minimize leakage by employing long columns, on the order of 8 ft, and to insure that the acidified influent wastes were free of suspended matter.

WASTE TREATMENT PLANT AND OPERATION

On the basis of the above laboratory investigations, a facility for waste treatment was designed and constructed. An existing compartmented concrete structure and tile leaching field were available for use and were therefore incorporated into the design. A diagram of the resulting treatment facility is shown in Fig. 3.

The wastes originate in the animal feed building where the beagles receiving the Sr⁸⁰ enriched food are housed. The cages are washed down with demineralized water several times a day and the wastes flow by gravity to a sump in the waste treatment building. From the sump, regulated volumes of waste are pumped into a 5000-gal Imhoff settling tank. The settleable solids are removed in this tank, the solids passing through a slot in the bottom of the flow-through compartment into an anaerobic digestion chamber. Retaining baffles at the liquid surface of the tank are designed to prevent floating material from passing farther through the system.

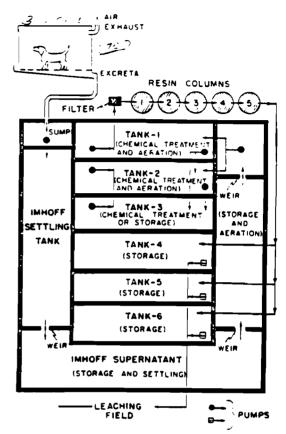


Fig. 3. Radioactive waste treatment plant (schematic representation).

One of the problems associated with this aspect of the waste treatment is the matter of dog hair floating on the surface. Periodic skimming of the surface of the tank has been necessary to remove the hair. An overflow weir separates the Imhoff settling tank from the first of two 5000-gal collection tanks, where additional settling takes place. The second tank originally served only as a collection and storage tank, but is currently being used for aeration prior to pumping to the chemical treatment tanks.

A system of pumps, manifold valves and gauges permit a high degree of flexibility in the subsequent treatment of the wastes following sedimentation. Further treatment of the settled wastes is conducted on a batch basis, each batch consisting of approximately 5000 gal. At various times settled waste is pumped into either Tank 1 or 2 (Fig. 3) until batch volume is reached.

In order to further clarify the wastes, acration may precede chemical flocculation. If aeration has affected a degree of clarification and decontamination, the supernatant is transferred to a subsequent tank for more efficient chemical treatment. Samples of the batch are then taken and optimum dosages of chemical coagulant and acid determined in the laboratory by conventional jar tests. Alum and ferric sulfate have both been tried as coagulants, with ferric sulfate currently being used. The pH adjustment has been made with concentrated hydrochloric acid. Compressed air distributed through submerged diffuser pipes in the tanks is used to mix the wastes and chemicals to enhance flocculation. A minimum of 24 hr is usually necessary for scitling of the floc before pumping the supernatant liquid to the next phase of treatment. The sludge from the flocculation step is removed periodically and added to the influent waste for distribution in the sludge compartment of the Indioff tank.

Following chemical treatment the liquid can be chlorinated, if necessary (pH above 4), and then pumped through a pressure filter of sand and activated carbon, followed by a cotton plug filter capable of removing particles as small as 5 μ and then through 5 ft^3 of ion exchange resin.

The resin bed is subdivided into a series of five columns, each 9 in. in diameter and 3 ft in length. The metal canisters are charged with 1 ft³ of Dowex 50×8 , 20-50 mesh cation resin in sodium form. Nylon sacks are used to contain the resin in order to permit easy removal of exhausted, contaminated resin with a minimum of handling. These are ultimately disposed of by offsite burial. Application rates to the resin columns have been on the order of 1 gal per min/ft² of resin

Effluents from the resin bed pass into storage tanks for radioassay and radioyttrium decay prior to discharge into the underground leaching field. If necessary, the contents of any of the storage tanks can be reprocessed. Suitable sampling valves are strategically located throughout the system to permit the contents of any tank to be sampled, as well as the effluents from the filters, or any of the resin segments.

RESULTS AND DISCUSSION

The actual chronological sequence of events

was such that the lowest level of Sr⁹⁰ feeding was initiated first, and with the progressive development of the program, higher levels of strontium were added as well as larger numbers of dogs in all levels, until the present capacity of the available dog facility had been reached.

During 18 months of waste processing, twenty-seven batches of radioactive waste were treated, amounting to over 116,000 gal of liquid and in excess of 14.5 me of Sr⁹⁰. Batch treatment data are summarized in Table 3. The apparent increase in pH with succeeding batches is due to the preclarification aeration in batch 18 and 21–27. It has been noted that preacration is accompanied by the release of ammonia, and a decrease in the buffering capacity of the wastes.

Prior to ion exchange, the lengthy Sr²⁰ separation procedures are not routinely performed in measuring radioactivity concentrations. Therefore, it will be noted that the decontamination evaluations compare the final Sryo concentrations to net β activity. The high Sr⁹⁰ levels handled initially do not warrant exhaustive analysis for radioactivity as the Sr⁹⁰ and net β values are essentially the same. Table 4 shows typical comparisons of Sr^{90} and net β values for wastes just prior to ion exchange. Following resin treatment such reasoning is no longer valid as the small amounts of K40, etc. introduce a large error in a relatively small number. All samples of ion exchanged wastes therefore require the rigorous Sr⁹⁰ separation procedure.

The first twelve batches of waste were coagulated with the use of alum but it became increasingly difficult to achieve adequate clarification and a change was made to ferric sulfate. Continued use has been made of ferric sulfate with satisfactory results. The reasons for the inability to achieve adequate clarification with alum are unknown, although a decrease in the temperature of the waste because of winter weather and change in waste characteristics as more dogs were added to the feeding program were both probably contributing factors. Ferric sulfate was not used initially because laboratory tests had shown that alum would give adequate results with the production of smaller quantities of sludge. It had been determined experimentally that optimum removal of Sr⁹⁰ by the cation exchange resins would be achieved when the

Table 3. Batch treatment data

	p	ப	Radioact	ivity (µc/ml)	
Batch number	Before chemical treatment	Influent to resin columns	Before chemical treatment (net B	Discharged to leaching field (Sr ¹⁰)	Vol um e ml)
1	7.0	5.1	5 × 10-7	0.38 - 10-7	0.326 > 107
2	6.5	3.7	8	0.17	1.310
3	7.1	4.6	14	0.13	1.491
4	7.1	4.0	26	0.16	1,703
.5	6.8	4.0	27	0.21	1.836
G	6.9	3.0	77	0.08	1.904
7	_	5.0	200	0.73	1.798
8	7.2	5.0	170	0.50	1.643
9	7.5	5.5	165	2.43	1.688
10	6.8	3.5	235	0.51	1.3 66
11	7.2	4.5	230	0.61	1.306
12	7.8	4.0	260	0.09	1.662
13	7.5	3.5	230	0.04	1.313
14	7.1	3.0	255	0.48	1.601
15	7.4	3.0	330	1.84	1.351
16	7.3	3.0	480	0.06	1.832
17	7.7	3.0	440	80. 0	1.366
18	8.0	2.5	400	0.01	1.964
19	7.0	3.0	450	0.08	1.813
20	7.8	3.5	510	0.01	1.514
21	8.3	3.8	54,9	0.41	1.817
22	8.7	3.0	650	O.(Hi	1.855
23	8.6	2.9	750	0.18	1.855
24	7.8	3.0	620	0.42	1.877
25	8.6	2.7	500	0.11	1.821
26	8.3	2.9	570	0.10	1.893
27	8.6	2.8	400	0.12	1.990

Note: Batches 1-12 were coagulated with 200-450 mg/l alum, nos. 13 and 14 required both alum and ferric sulfate, while batches 15-27 were coagulated with 125-250 mg/l ferric sulfate.

Table 4. Comparison of Sr⁹⁰ content to net β activity in settled wastes before chemical treatment

Batch number	μμ c Sr ⁹⁰ /ml.	μμc Net β/ml.	Sr ⁹⁰ /Net β
5	2.85 ± 0.02	2.98	0.96
8	14.37 ± 0.15	15.1	0.95
12	17.80 ± 0.17	17 .2	1.03
20	37.31 ± 0.22	34.8	1.07
26	39.81 ± 0.23	42.2	0.94

pH of the waste was below 4. Since the settled waste was essentially neutral, concentrated hydrochloric acid was added in order to carry out the coagulation in an acid state.

The DF following ion exchange treatment appears to be directly influenced by the clarity of the liquid and its rate of application. To date, those batches which have proved difficult to flocculate, and have given effluents which might be termed cloudy, have been the ones which have given the lower DF's through the resin columns.

Chlorination of the clarified waste prior to resin treatment in order to minimize bacterial growth and subsequent fouling or blinding of

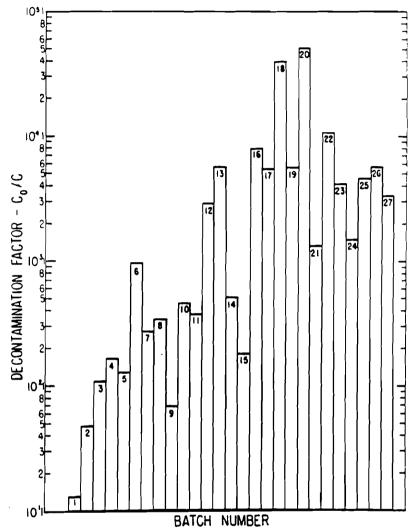


Fig. 4. Decontamination of Sr⁹⁰ achieved by waste treatment.

the resin was attempted with several batches. However, upon chlorination a fine floc was formed which carried onto the resin, and the resulting resin DF was lower than expected. Bacterial growth is no longer a problem at the pH values now being employed.

Fluctuations in effluent Sr⁹⁰ concentration may be attributed to many factors, including experience gained in operation of the plant. The data presented in Fig. 4 show the general upward trend in Decontamination Factor

(DF)* which has been achieved with succeeding batches; from a DF of 13 with batch 1 to a DF of 5×10^4 for batch 20. Factors influencing the DF are aeration efficiency, the degree of success of the flocculation stage, rate of application of the clarified waste to the resin columns, and leakage problems from faulty valves.

[•] In this case, Decontamination Factor $= \text{Co/C}, = \frac{\text{total } \beta \text{d/m/ml in settled waste}}{\text{Sr}^{90} - \text{Y}^{90} \text{ d/m/ml in final effluent.}}$

For batches 1-12 the first 3 ft³ of resin were removed following treatment of each batch, their volume replaced with fresh resin, and the new canisters placed in the rear positions of the flow pattern. In subsequent batches the number of canisters recharged was dictated by the results obtained on the previous batch and also by the desire to experiment with the system under varying conditions.

Because of the rapidly changing characteristics of the incoming waste stream, particularly with respect to Sr⁹⁰ concentration, along with the long detention time of up to 3 months provided in the primary sedimentation zone, it has not been possible to evaluate carefully the DF obtained by simple primary sedimentation. Best estimates are that the radioactivity is decreased by 10-50 per cent in its passage through the first three tanks. Chemical coagulation reduces the remaining activity by 25-50 per cent. The pressure filter of activated carbon and sand, along with the cotton plug filter preceding the resin columns, effects an additional small degree of decontamination.

The residual sludge from each batch clarification is transferred to the primary settling (Imhoff) tank. Digestion occurring in this chamber maintains the sediment at a relatively thin and constant layer. It is estimated to occupy a volume equal to about 100 gal although over 100,000 gal of waste have been processed over the past 2 years. This radioactive sediment will ultimately be concentrated, solidified, and if necessary, disposed of offsite.

The goals set for the concentration of Sr⁹⁰ in the effluent from the treatment plant were the guides set by AEC regulation Title 10 Part 20(3) which permit concentrations of Sr⁹⁰ in the water of an off-site population to be $10^{-7} \mu c$ Sr⁹⁰/ml on a yearly average. These limits were exceeded in six batches, and five of these batches were reprocessed to reduce their activity level. The net result was that the concentration of $1.0 \times 10^{-7} \mu c \text{ Sr}^{90}/\text{ml}$ was exceeded in two of the twenty-seven batches discharged into the leaching field, and the average concentration of all twenty-seven batches was $3.5 \times 10^{-8} \mu c$ Sr90/ml. The relatively high activity levels in the discharged wastes constituting batches 9 and 15 (Table 3) were due to faulty valves which permitted raw waste contamination of otherwise

efficiently treated batches. A total of 15.5 uc of Sr⁹⁰ was thus deposited in the leaching field. The nature of the soil surrounding the leaching field is such that its high clay content (20 per cent montmorillonite clay) would exert ion exchange properties and greatly restrict the movement of the Sr⁹⁰ through the ground.

A study of the removal of radioactivity by the ion exchangers was undertaken for batch 16. A total of 4840 gal of chemically clarified waste was treated by ion exchange and radiochemical analyses performed on the effluents from the resin with respect to time. Samples of the resin effluents progressively increased in total activity. having $0.2 \times 10^{-7} \,\mu c/\text{ml}$ after 900 gal had been treated, $0.3 \times 10^{-7} \mu c/ml$ after 1700 gal and $0.8 \times 10^{-7} \,\mu \text{c/ml}$ following treatment of 3650 gal. The average total beta activity in the holding tank after the entire batch had been processed was $0.4 \times 10^{-7} \,\mu\text{c/ml}$. Of this total beta activity only $0.06 \times 10^{-7} \,\mu\text{c/ml was Sr}^{40}$. The other beta activity present was due to natural background as well as the shorter halflived daughter isotope You which passes the exchange resins in greater amounts than does the strontium. This had been predicted in the initial laboratory investigations and was one reason for providing storage tanks for the resin effluents prior to discharge in order to permit the waste to reach secular equilibrium.

The first three ion exchange cartridges used to treat batch 16 were removed and counted individually in a whole-body counter⁽⁴⁾ and their Bremsstrahlung emission compared with a standard containing radioactive strontium. While this evaluation is not considered entirely quantitative, it has been found to be within 10 per cent of the estimate of the total beta radioactivity contained in the influent to the resin columns. Approximately 70 per cent of the radioactivity was contained in the first ft³ of resin, the second segment contained an additional 20-25 per cent while the third resin segment retained approximately 3 per cent.

SUMMARY

The need for continuous treatment of organic wastes from a large colony of dogs on a diet containing various amounts of Sr²⁰ required the design and construction of a moderate sized waste treatment plant. The contaminated

wastes contain in excess of $5 \times 10^{-8} \mu c \text{ Sr}^{90}/\text{ml}$ and are produced at approximately 200-500 gal/day. Decontamination depends upon efficient utilization of the principles of primary sedimentation, aeration, chemical clarification and filtration prior to passage of the waste through 5 ft³ of cation exchange resin. The ion exchange phase of the treatment process is operated as a non-regenerative system.

Average discharges of final effluents to an underground leaching field have not exceeded the current permissable concentration in drinking water for Sr⁹⁰. Decontamination Factors up to 5 < 10⁴ have been obtained in the treatment of over 116,000 gal of waste. Cost of treatment is currently estimated at less than 15 cents/gal, including material, labor and plant amortization.

Additional investigative work is being conducted to determine the influence of various factors on the ion exchange decontamination process. Included in these are the effect and fate of the organic matter in the waste in ion exchange treatment and, through use of direct counting of the ion exchange resin columns in a

whole-body counter, factors influencing sorption and ultimate desorption of the radionuclides in a particular exchange column.

Acknowledgments—The authors wish to acknowledge the assistance of the Division of Radiation Safety, University of California, Berkeley, in the designing of the waste treatment plant. Professor W. J. KAUFMAN has provided invaluable guidance in its design and operation. The cooperation of Messrs. A. HUFF, C. POTTS and R. KROLL in the mechanical operation of the plant is appreciated.

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APPENDIX B

CHEMICAL DATA

APPENDIX B.1

CHEMICAL ANALYSIS DATA FROM EMSC

ENVIRONMENTAL MONITORING & SERVICES, INC.* Formerly Environmental Monitoring & Services Center of Rockwell International Corporation 2421 West Hillcrest Drive Newbury Park, California 91320 (805) 498-6771

11 October 1984

Mr. Jerry Carroll Atomics International 071-NB02 Canoga Park, CA

Dear Jerry:

Four soil samples were sent by Eockwell-ESG to our Laboratory for testing. Each sample was tested according to EPA organic analysis protocol for volatile organics (EPA Method 624), semivolatile organics (EPA Method 625), pesticides (EPA Method 608), and metals (California CAM method).

The analytical data for volatile, semivolatile and metals are summarized in Tables I, II and III. The HSL compounds seen above the method blank level were methylene chloride (Table I) and bis(2-ethyl hexyl) phthalate (Table II) in Sample Nos. 140 and 143. None of the HSL compounds were seen above the method detection limits in the Sample Nos. 137 and 139.

The pasticides were found to be below detection limits. Table IV gives the detection limits for the volatile, semivolatile and pasticide compounds of the Hazardous Substance List (HSL) and Tables V, VI and VII give the surrogateremovery for the volatile, semivolatile and pasticide compounds. Reconstructed total ion chromatograms for the volatiles are presented in Figures 1-5, and semivolatiles in Figures 6-10. The gas chromatograms for the pasticide analysis are shown in Figures 11 through 15.

If you have any questions, please don't hesitate to call me.

Sincerely.

George Colovos, Ph.D.

Manager, Technical Operations

/ald

Enclosures

"A wholly owned subsidiary of COMBUSTION ENGINEERING, INC.

TABLE I

VOA Compounds in the Soil Samples

Compound	Concentration, ug/kg (wet weight)				
	<u>#137</u>	<u>#139</u>	<i>§</i> 140	1143	
methylene chloride	_	_	12	10	

TABLE II

Compound	Concentration, ug/kg (wet weight)				
	<u> </u>	<u>#139</u>	<u>#140</u>	<u> </u>	
bis(2-ethyl hexyl) phthelate		_	3300	2800	

TABLE III

	l		mg/kg in wet sm	mple	
	#137	# 139	#140	#14 <u>3</u>	STLC
Sb	<0.2	<0.2	<0.2	<0.2	157
44	5.3	4.6	7.4	7.6	53
Ba	170	230	180	210	1050
Be	<2	<2	<2	<2	7.8
: 4	<2	<2	<2	<2	10.5
Gr (VI))	į	į		53
Cr	51	53	27	53	5880
ک	16	24	33	15	840
Cu	41	35	20	40	263
?	23.4	31.3	30.2	72.6	1890
?b	<13	<13	<13	<13	53
ig	<0.5	<0.5	<0.5	<0.5	- 2.1
5 0	<500	<500	<500	<500	3675
11	<100 _.	102	<100	115	210
ie	<1	<1	<1	<1	10.5
\s	<2	<2	<2	<2	52.5
1 1	<50	<50	<50	<50	73.5
7	<200	<200	<200	<200	.252
Žn.	80.2	74.1	45.7	69.4	2625
	15.92	14.52	5.92	11.12	<u> </u>

TABLE IV

Hezerdous Substance List (HSL)* and Contract Required Detection Limits (CRUL)***

		Det	ection Limits
		Low Water	Low Soil/Sediment
Volstiles	CAS Sumber	ug/L	ug/Kg
1 (0.1	74-87-3	10	
1. Chlorosthana	74-63-9	10	10 - 10
2. Bronomethans	75-01-4	10	10
3. Vinyl Chloride			
4. Chloroschane	75-00-3	10	10
5. Mathylene Chloride	75 -09- 2	5	5
6. Acatone	67-64-1	10	10
7. Carbon Disulfide	75-15-0	.5	3
8. 1.1-Dichloroethene	75-35-4	S	5
9. 1.1-Dichioroethana	75-35-3	5	5
10. trans-1,2-Dichloroethene	1.5 6-6 0-5	5	5
11. Chloroform	67 -66- 3	5	5
12. 1,2-Dichloroethene	107 -06- 2	5	5
13. 2-Butanous	78 -9 3-3	10	10
14. 1,1,1-Trichloroechene	71 <i>-</i> 55 -6	5	5
15. Carbon Tetrachloride	56-23-5	5	5
16. Vinyl Acetata	108-05-4	10	10
17. Bromodichloromethane	75 -2 7- ↓	5	5
18. 1,1,2,2-Tetrachioroethese	79-34-5	5	· 5
19. 1,2-Dichloropropane	78 -67-5	5	· 5
20. crans-1,3-Dichloropropens	10061-02-6	5	5
21. Trichloroschene	79-01-6	5	5
22. Dibroschloromethane	124-48-L	5	5
23. 1,1,2-Trichloroethene	7900-5	5	5
24. Benzene	71 →3 -2	5	5
25. cisel.3-Dichloropropess	10061-01-5	5	5

(continued)

TABLE IV (Continued)

		Dete	ection Limits
		Low Water	Low Soil/Sediment
Volatiles	CAS Number	ug/L	ug/Kg
26. 2-Chloroethyl Vinyl Ether	110-75-8	10	10
27. Bromoform	75-25-2	5	5
28. 2-Hexanone	591-78-6	10	ro
29. 4-Methyl-2-pentanone	108-10-1	10	10
30. Tetrachloroethene	127-18-4	5	5
31. Toluene	108-88-3	5	5
32. Chlorobenzene	108 -9 0-7	5	5
33. Ethyl Bensene	100-41-4	5	5
34. Styrene	100-42-5	5	5
35. Total Tylenes		5	· Š

^{*}Madium Water Contract Required Detection Limits (CEDL) for Volatile HSL Compounds are 100 times the individual Low Water CEDL.

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Madium Soil/Sediment Contract Required Detection Limits (CEDL) for Volatile ESL Compounds are 100 times the individual Low Soil/Sediment CEDL.

TABLE IV (Continued)

			ection_Limits
		Low Water	Low Soil/Sediment
Semi-Volatiles	CAS Number	ug/L	ug/Kg
36. H-Hicrosodimethylamine	62-73 -9	10	330
37. Themal	108 -9 5-2	10	330
38. Aniline	62-53-3	10	330
39. bis(2-Chloroethyl) ether	111-44-4	10	330
40. 2-Chlorophanol	95-57-8	10	330
41. 1.3-Dichlorobenzene	541-73-1	10	330
42. 1.4-Dichlorobenzene	106-46-7	10	330
43. Bensyl Alcohol	100-51-6	10	330
44. 1.1-Dichlorobenzene	95-50-1	10	. 330
45. 2-Machylphanol	95-48-7	10	330
46. bis(2-Chloroisopropyl)			
ather	39638-32-9	10 '	330
47. 4-Machylphenol	106-44-5	10	330
48. B-Hitroso-Dipropylamine	621-64-7	10	330
49. Herschlotpethane	67-72-1	10	330
50. Hitrobensens	98-95-3	10	330
		•	
51. Isopherona	78-59-1	10	330
52. 2-Hitrophenol	88-75-5	10	330
53. 2,4-Dimethylphenol	10 5-6 7 -9	10	330
54. Benenic Acid	65650	50	1500
55. bis(2-Chloroethoxy)			
methene	111-91-1	10	130
56 2,4-01chlorophenol	120-63-2	10	330
57. 1.2.4-Trichlorobensene	120-62-1	10	· 330
58. Rephthelene	91-20-3	10	330
39. 4-Chlorosniline	106-47-8	10	330
60. Hexachlorobutadiens	87-68-3	10	330
61. 4-Chloro-3-aschylphenol			
(para-chioro-maca-cresol) 5 9- 50-7	10	330
62. 2-Hethylnaphthalene	91-57-6	10	3 30
63. Hexachlorocyclopentadisne	77-47-4	10	330
64. 2,4,6-Trichlorophenol	88-06-2	10	330
65. 2.4.5-Trichlorophenol	95-95-4	50	1600

(continued)

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330	70	\$0 - 35 -8	Jenso(e)pyrene	100
230	01	207-08-9	lenso(k) fluoranthene	. 66
230	٥t	2−66− 502	Seaso(b) (luotanthene	. 86
220	at	0 -48- 711	M-g-octyl Mchaffica	. 76
330	01	578-01-9	Chrysena	. 96
apr	70	4-19- 411	bis(2-echylhemyl)phchalace	• 64
330 330	70	£-55 -9 5	Jenzo(s)snchrzeene	
099	OZ	1 -76- 16	1,1'-Dichlorobemsidine	
	70	7 -83- 28	Sucyl Sensyl Phchalace	
330	01	0-00-671	Tyrene	
330	O.	0-00-821		
0091	90	5-49-26	persy (Tere	*06
330	01	30 0-11- 0	Tangarateur!	
330	70	2-7/-78	Di-m-bacylphthatate	
330	ot	1-21-021	Anchtagene	. 78
330	οτ	9-10-59	Phenazzhrene	. 98
0091	OS	2-99-TB	?emsechlorophenol	. 28
330	70	I-7/-8TI	Berreibloro berreib	. 48
330	ot	E-66-101	4-Sromophenyl Phenyl ether	. 28
330	70	9-0E-98	H-61 trosodipheny Lemine	. 28
0091	20	234-23-1	Locadqivdzam-S-orsinid-6,2	.18
-0091	OS	700-07- - e	anilimatril-4	.08
220	70	7-57-88	Tinoren	
330	70	E-57-2007	78629	. • •
766	•		e-Chlorophemyl Phemyl	.87
220	70	7 -99-7 8	ОТВЕРТРИСРИТИСЕ	
330	70	z-0z-909	2,6-binitrocoluene	
700	U.	• •• ••	•	
330	70	131-17-5	2,4-0tnicrocoluene	.27
330	01	6-79- 227	namodiu	. 47
0091	DS	Z-Z0-00T	4-H1 Crophenol	. 27
0091	DS	5-8Z-15	2,4-0inicrophenol	.27
330	Dī	83-35-6	Acensph:hene	.17
0091	or	Z-60-66	Sailinsorriff-C	•0/
	90	_	Ac emaphthylene	
320	01	508 -36-8 07	Dimerkyl Phehalace	
330	70	E-11-1E1	S-A1 Crosniline	
0091	05	7-7L-88	2-Chloronaphchalene	
330	70	7-82-16	200 (2424====20 (40-5	77
ug/Kg	ៗ/2ីព	CAS Number	Semi-Volatiles	

Detection Limits
Low Weter Low Soil/Sediment

TABLE IV (Continued)

TABLE IV (Continued)

		Des	ection Limits	
		Low Water	Low Soil/Sediment	
Pesticides	CAS Number	ug/L	ug/Kg*	
104. alpha-BHC	319-54-6	0.05	2.0	
105. beca-BHC	319-65-7	0.05	2.0	
106. delta-BHC	319-86-8	0.05	2.0	
107. gamma-BHC (Lindane)	58-89-9	0.05	2.0	
108. Heptachlor	76-44-8	0.05	2.0	
109. Aldrin	309-00-2	0.05	2.0	
110. Reptachlor Epoxide	1024-57-3	0.05	2.0	
III. Endosulfan I	959-98-8	0.05	z. 0	
112. Dieldrin	60-57-l	0.10	4.0	
113. 4,4'-DDE	72 -55-9	0.10	4.0	
114. Endrin	72-20-8	0.10	4.0	
115. Endosulfan II	33213-65-9	0.10	4.0	
116. 4,4'-DDD	72-54-8	0.10	4.0	
117. Endrip Aldehyde	7421 -9 3-4	0 10	4.0	
118. Endosulfan Sulface	1031-07-8	0.10	4.0	
119. 4,4'-DDT	50-29-3	0.10	4.0	
120. Endrin Ketone	53494-70-5	0.10	4.0	
121. Methoxychlor	72 →3 -5	0.5	20.0	
122. Chlordane	57-74-9	0.5	20.0	
123. Toxaphene	6001-35-2	1.0	40.0	
124. AROCLOR-1016	12674-11-2	0.5	20.0	
125. AROCLOR-1221	11104-28-2	0.5	20.0	
126. AROGLOR-1232	11141-16-5	0.5	20.0	
127. AROCLOR-1242	53 469- 21 -9	0.5	20.0	
128. ABOGLOR-1248	1 2672-29-6	0.5	20.0	
129. AROCLOR-1254	11.097-69-1	1.0	40.0	
130. AZOGLOR-1260	1109 6-8 2-5	1.0	40.0	

Madium Water Contract Required Detection Limits (CRDL) for Pesticide HSL Compounds are 100 times the individual Low Water CZDL.

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finedium Soil/Sediment Contract Required Detection Limits (CRDL) for Pesticide HSL compounds are 60 times the individual Low Soil/Sediment CEDL.

^{*} Wherever the term "priority pollucant(s)" is used in this contract and in any references cited in this contract, it is intended to mean "Hazardous Substances List (HSL) Compound(s)," which include all compounds listed in this Exhibit.

^{**} Specific detection limits are highly matrix dependent. The detection limits listed herein are provided for guidance and may not always be achieveble.

TABLE IV (Continued)

		Detection Limits		
Semi-Volaciles	CAS Number	Low Water	Low Soil/Sediment ^d ug/Kg	
101. Indeno(1,2,3-cd)pyrene 102. Dibenx(a,h)anthracene 103. Benzo(g,h,i)perylene	193-39-5 53-70-3 191-24-2	10 10 10	330 330 330	

^{**}Hedium Water Contract Required Detection Limits (CEDL) for Semi-Volatile HSL Compounds are 100 times the individual Low Water CEDL.

dedium Soil/Sediment Contract Required Detection Limits (CZDL) for Semi-Volatile ESL Compounds are 60 times the individual Low Soil/Sediment CZDL.

TABLE V

VOA Percent..Sūrrogate Recovery

Surrogata Compounds (Approved recovery range)	1				
	#137	#139	#140	#143	Method Blani
SURR-1 (1,2-dichloroethane-d ₄)	95	91	96	93	98
SURR-2 (benzene d ₆)	115	118	126	128	118
SURR-3 (toluene d ₈)	129	93	96	98	104
SURR-4 (p-bromofluorobenzene)	132	91	95	92	108

TABLE VI

ENA Percent Surrogate Recovery

Surrogate Compounds (Approved recovery range)	Percent Recovery				
	#137	#139	#140	#143	Method Blank
SURR-1 (2-fluorophenol)	114	89	56	63	56
SURR-1 (phenol-d ₅)	77	69 -	40	50	41
SURR-3 (nitrobenzene-d ₅	77	56	48	58	51
SURR-4 (2-fluorobiphenyl)	68	61	57	66	58
SURR-5 (2,4,6-cribromophenol)	93	96	32	44	30
SURR-6 (terphenyl-d ₁₄)	72	77	32	33	30 ·
·					

TABLE VII
Pesticide Surrogate Recovery

Surrogate Compounds (Approved recovery range)					
	#137	#139	#140	#143	Method Blank
Dibutyl chlorendate	87	83	93	84	90
				•	

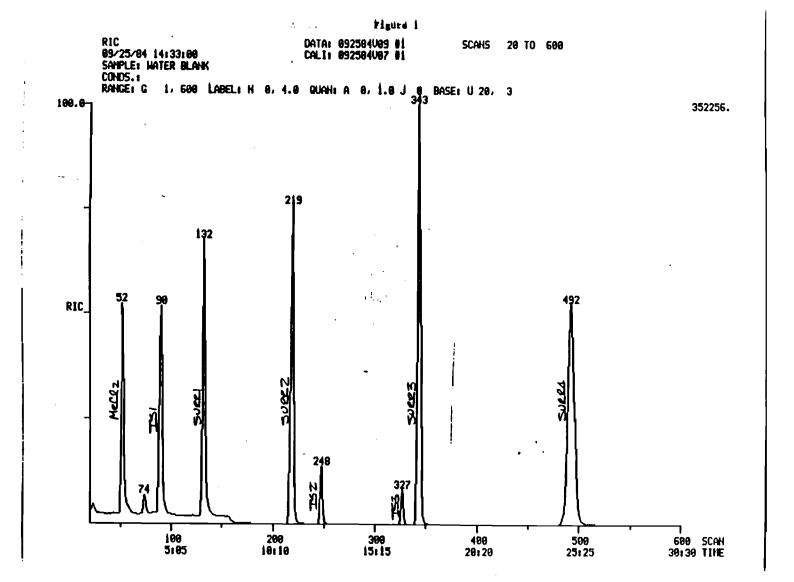
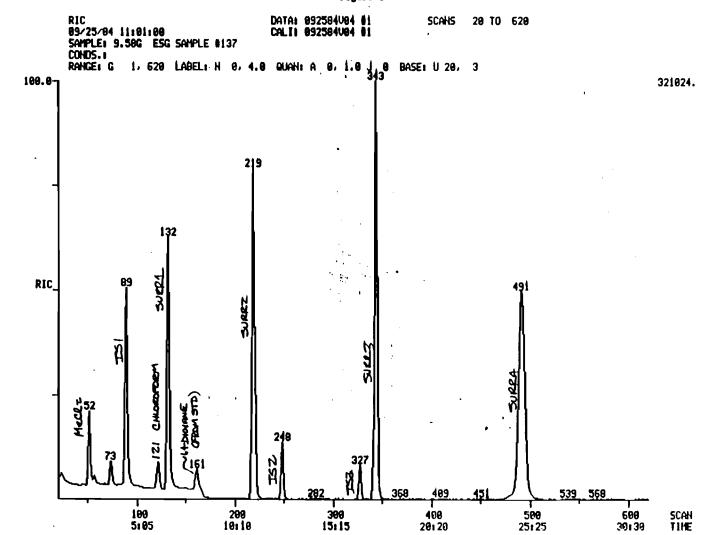


Figure 2



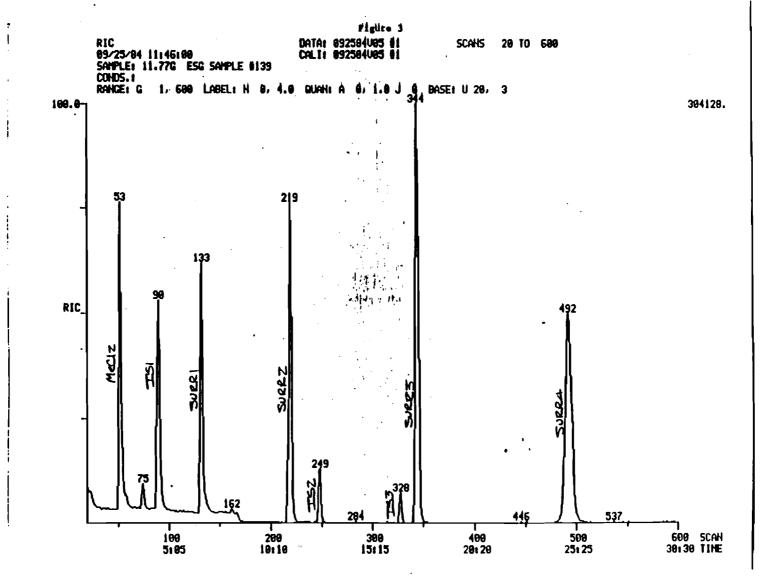


TABLE VII
Pesticide Surrogate Recovery

Surrogate Compounds (Approved recovery range)	1	Percen			
	#137	# 139	#140	1143	Mathod Blank
Dibutyl chlorendate	87	83	93	84	90
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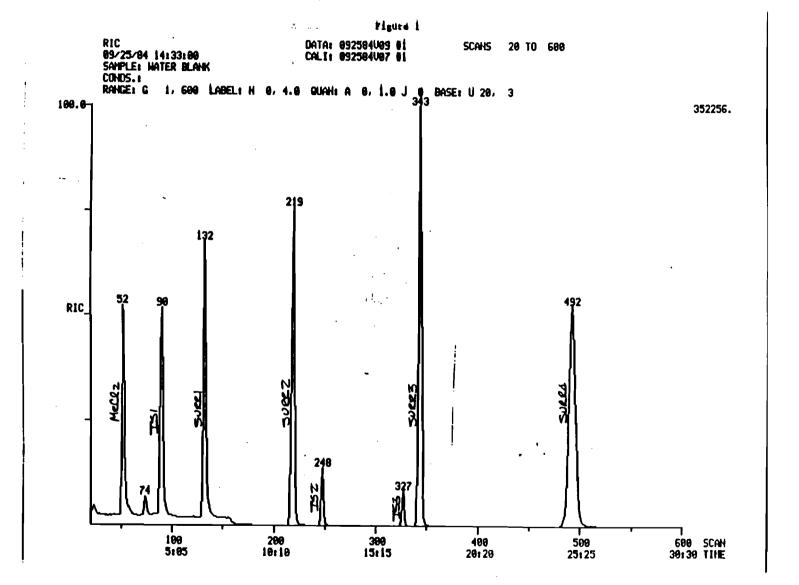
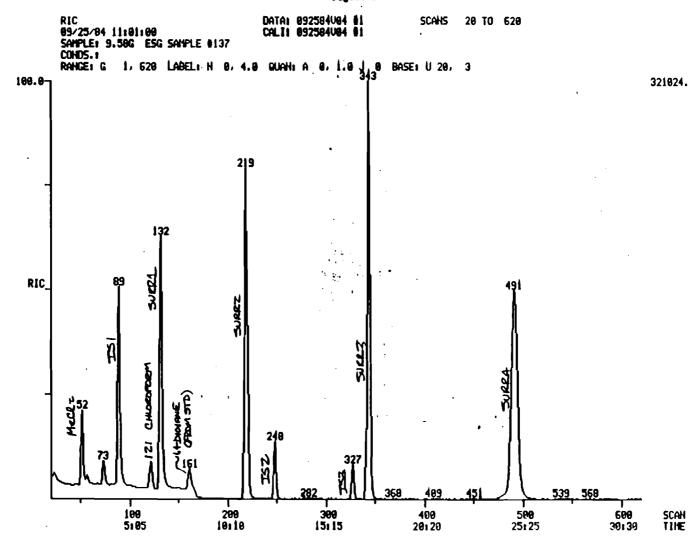
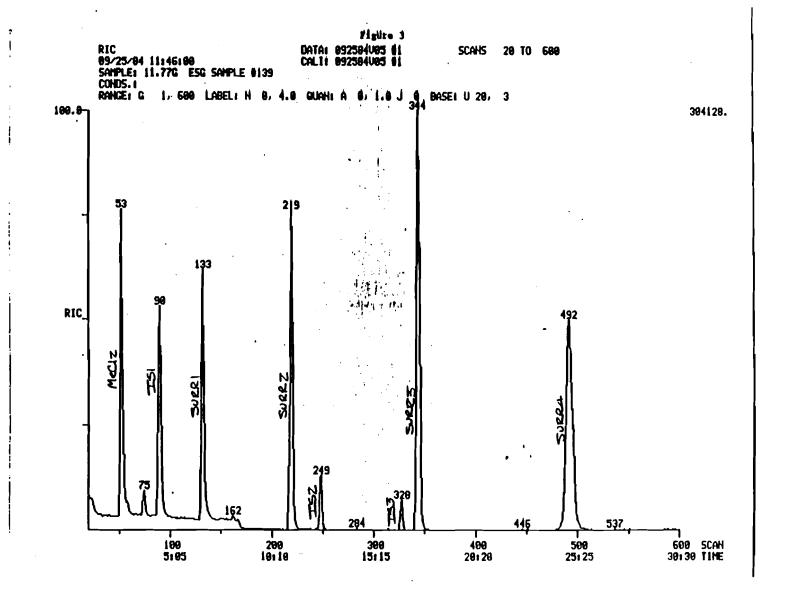
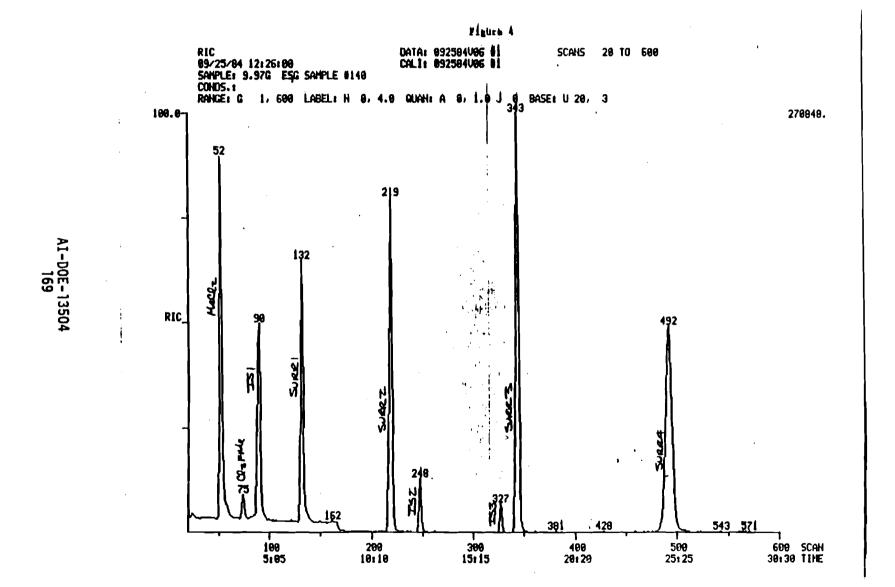


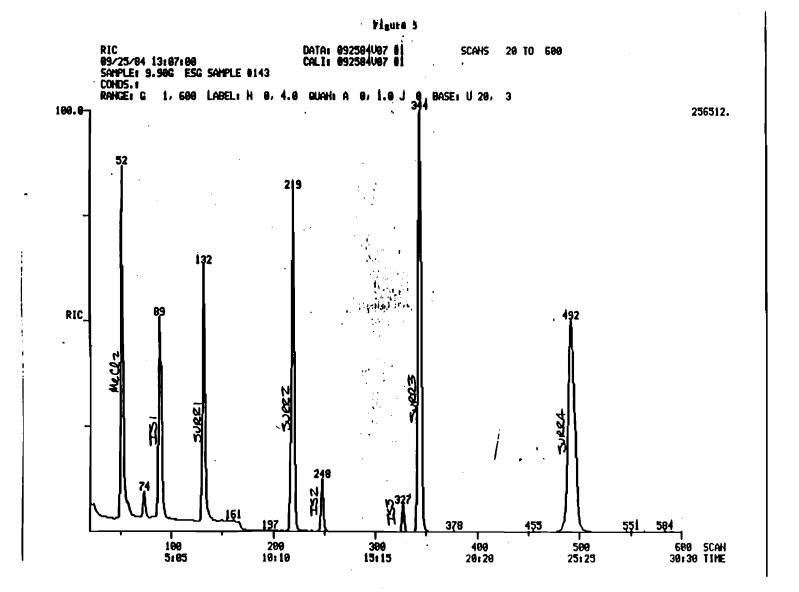
Figure 1

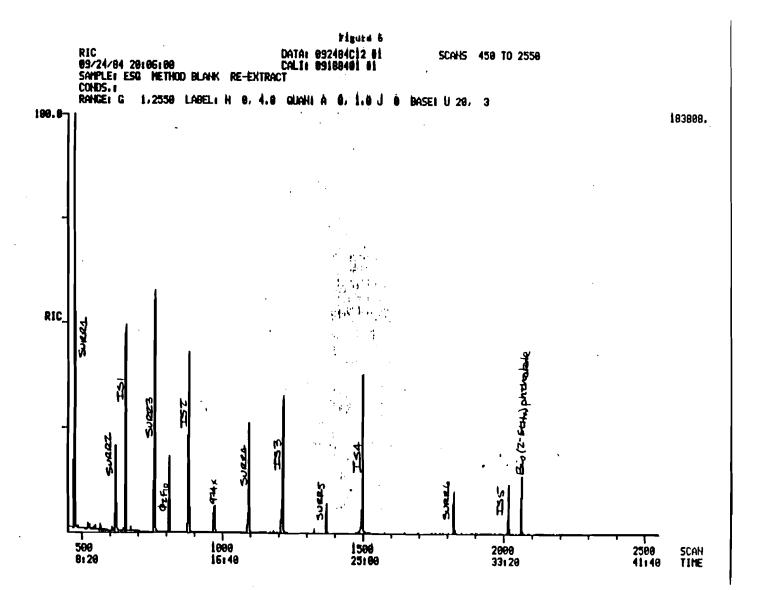




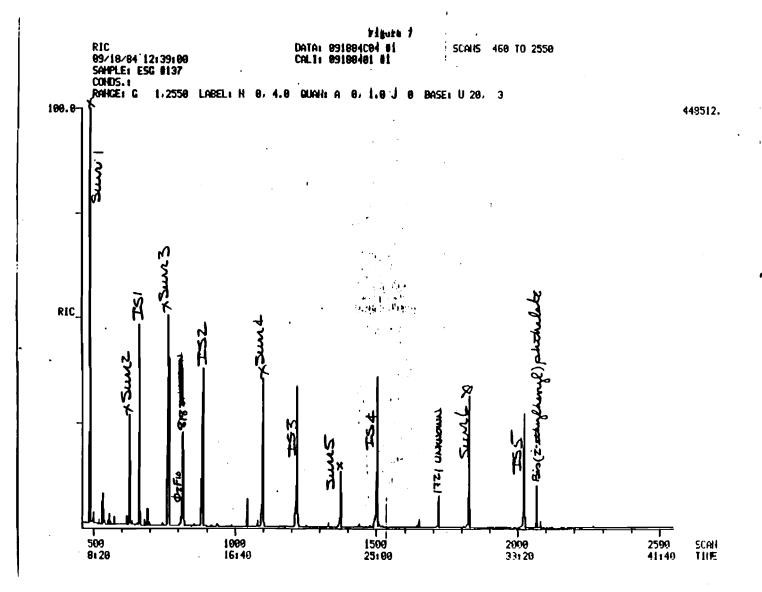


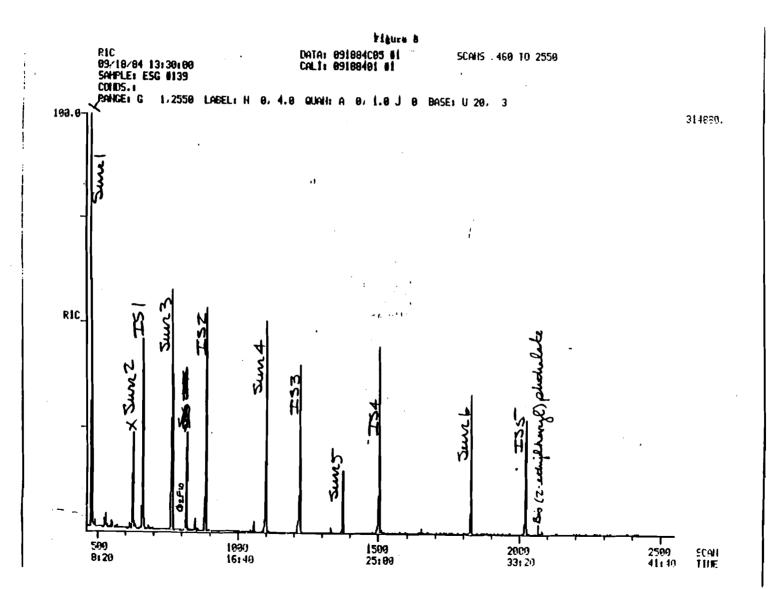




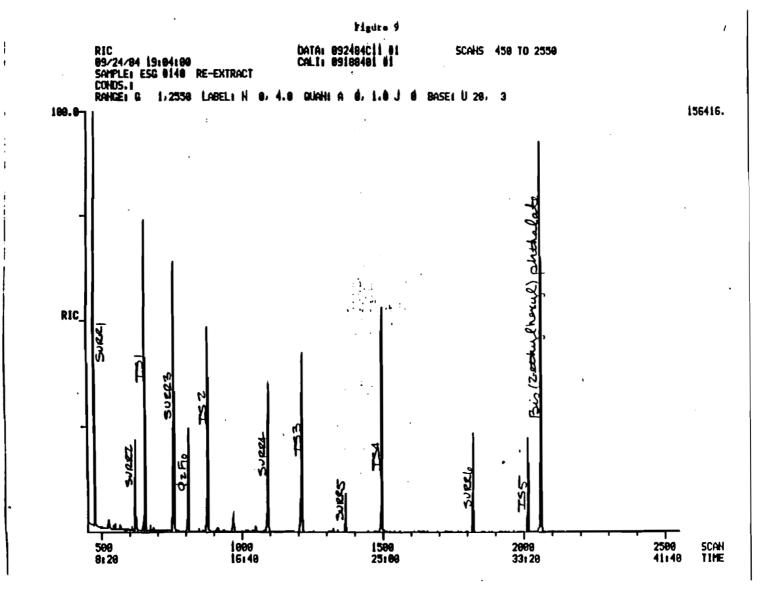












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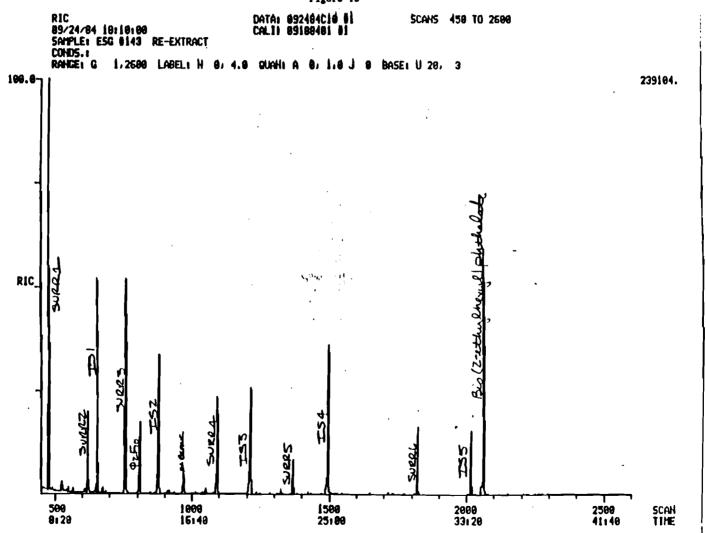
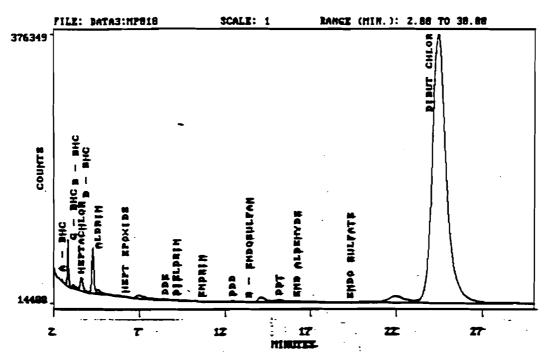


Figure 11



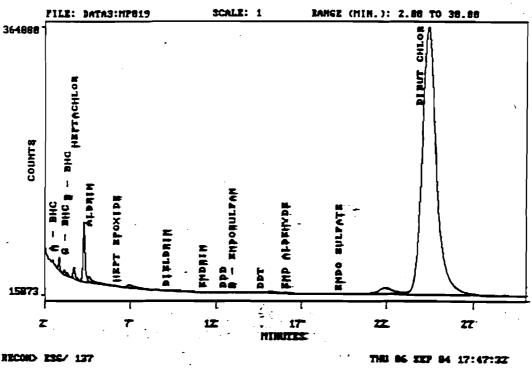
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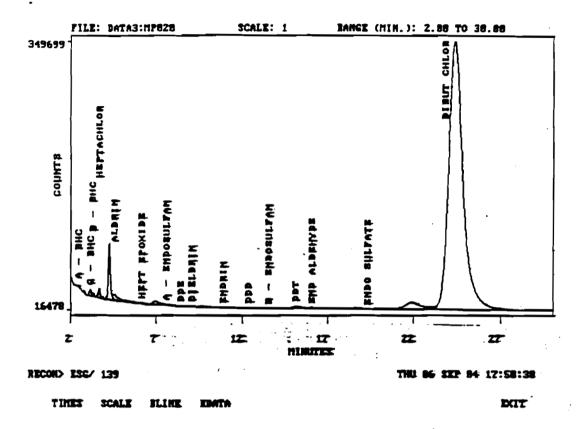




TIMES SCALE BLINE ROOT

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Figure 13





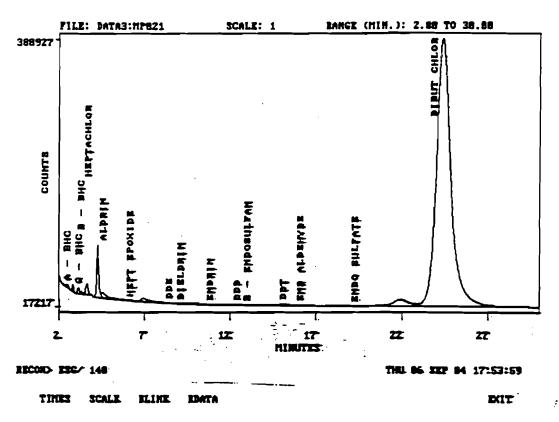
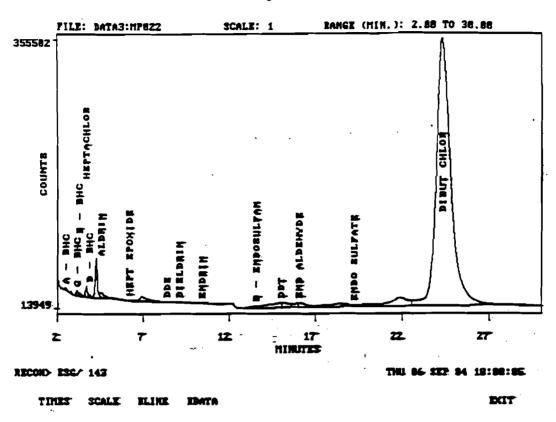


Figure 15



APPENDIX B.2

LIST OF EPA PRIORITY POLLUTANTS (REPRINT SUPPLIED BY EMSC)



Priority pollutants I-a perspective view

What are they? Toxic chemicals. How many are there? 129.

Complying with a 1976 court settlement, the U.S.

Environment Protection Agency is spending about \$60 million to obtain the necessary data for forthcoming regulations that are the beginning of a better way to monitor industrial wastewater discharges. Next month's authors present a cost-effective method to analyze for these pollutants

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Austin, Texas 78766
William A. Telliard
U.S. EPA
Weshington, D.C. 20460

One objective of this article is to relate the historical origins of EPA's Priority Pollutants and the development of the "Priority Pollutant Protocol." Most puople are unaware of the difficulties involved in providing methods for the necessary analysical support for these pollutants. A second objective is to summarize the status of the current analytical procedures in their present and still-developing forms.

A June 7. 1978, court settlement involving the EPA and several environmentally concerned plaintiffs (Natural Resources Defense Fund. Inc.: Environmental Defense Fund. Inc.: Businessmen for the Public Interest. Inc.: National Audubon Society, Inc.: and Citizens for a Better Environment) has commonly become known as the "EPA Consent Decrea." These groups brought suits against the EPA for failing to implement portions of the Federal Water Pollution Control Act (P.L. 92-500). One result of this stat required EPA to publish a list of toxic pollutants for which technology-based effluent limitations and guidelines would be required (ES&T. February 1978, p 154).

The Consent Decree dictates that.

The Consent Decree dictates that,
"... the (EPA) Administrator shall develop and promulgate regulations which shall establish and require achievement at the earliest possible.

TABLE 1
Point-cource categories 4

	Bath for presentation
Times grounds processing	12/79
Steam electric power plants	12/79
Leading was finishing	8/79
Iron and steel metulecturing	\$/80
Potrateusis rollning	10/79
hargens chemicale manufacturing	4/80
Textitle mills	12/79
Organic charticals manufacturing	8/80
Nonterrous metals manufacturing	3/80
Poving and realing mutarture	1/80
Paint and ink formulation and printing	4/80
Philips and inte	5/80
Priviling and publishing	1/81
Soop and desergent manufacturing Auto and other leundrine	7/20
Please and synthetic muserials	1/80 8/80
manufacturing	
Pulp and papercoard mile and converted	8/80
paper products	
Pubber processing	1/80
Missellaneous chemicals	.,
- Acheeves	8/80
Gum and wood chemicals	3/80
Posticidas	10/80
Premianalisais	7/80
Explosives municipality	7/80
Machinery and impohenical professio menulace	and .
Alument formers	10/80
Bellery musulecturing	10/80
Coil country	3/80
Copper forming	11/80
Foundhes	5/80
Pleases processing	5/81
Processin enernet	5/80
Mechanical products	3/81
Electrical and electronic components	10/80
Secreptions	10/80
Ore mining and draming	7/80
Cost mining	A/80

* The Calman Course recovery stretters for 21 industrial excession.

And the case of benefitting as sectoral filtrates at as CT Critical Cons.

time, cut in no case later than June 30, 1983, of effluent limitations and guidelines for classes and categories of point sources which shall require application of the best available technology (BAT) economically achievable for such category or class... The

intent Decree also requires new jource performance standards and pretreatment standards for 21 industrial categories (Table 1). In addition, EPA has decided to review public owned treatment works (POTWs) as a separate category.

The original Consent Decree contained a strict scheduling of contracts to be assued and dates for the required regulations to be promulgated (Table 1). The schedule originally gave contractors only 15 months to complete their analyses and evaluations. New dates, which will give EPA more time, are awaiting approval by the U.S. District Court.

Another component of the Consent Decree was a list of 65 compounds and classes of compounds (Table 2). A set of technology-based regulations are to be established for the control of the "65 pollutants" in all 21 point-source industrial categories. This list eventually formed the Toxic Pollutant List included in P.L. 92-500 under Part 307 (a) which concerns toxic materials.

Environmental and analytical chemistry play significant roles in obtaining data upon which these regulations are being based, but there were some details that were contied:

- Minimum detection levels were not specified.
- The list of 65 compounds and ciasses of compounds could include thousands of poliutants if all compounds in each of the classes and all organometallic compounds were considered.

- Standard methods for collecting and preserving the organic samples were unavailable.
- Standard methods for analyzing organics in complex wastewaters were unavailable.

Nevertheiess, contracts were let as mandated, samples were taken and analyses were begun. Concurrent with these activities. EPA chemists were trying to resolve some of the analytical problems caused by the Toxic Pollutant List. At an informal meeting in Kansas City in late October 1976, we proposed that the initial (Screening Phase) analyses for the organic pollu-Linus be conducted by gas chromatography-mass spectrometry (GC-MS). GC-MS was the only available technique that could identify a wide variety of compounds in many different matrices and in the presence of interfering compounds. Previous expersence with natural and drinking weter samples had shown that many compounds in water could be identified and sems-quantified at the I part per

TAR	uii 2.	35.	
	toxic pollutant list	34	
	•	37.	
	Acumphibate	31.	Historians (other than those fisted elecuture; includes chierophonylghunyl esters, brows-
_	Acrolein		phonylphonyl other, bladdichlarescopyl)
	Acrylanitrile		offer, bestfarred and medians, and paly-
•	Aldrew/Clinidren		chiarmini datani aturu
	Antimony and compounds	**	Halorrenan (after that these hased electronic
	'Arsenic and compounds		includes methylene chicade, methyl chicade,
_	Antonica		methyl bremide, bromolom, dichigropro-
	Bertine Bertine		manufacts, Pichingharmanian, dono-
		•	roditation from the contraction of the contraction
	Berythum and compounds Cadmium and compounds		. Hepachier and membelias
		40.	- Propagation and Pronamous
	Carbon tetragraphics	41.	
	Chigraine (technical miniture and metabolites) Chigrinalist becomes follow than dichloroberosess)	42	Heimchierodyctohoxene (eff legmers) Heimchierodyctopentadiene
	Chlorinated etheres (including 1.2-dichloroeth-	43	Lacoferroria
12.	ans, 1,1,1-irichlorosthens, and hexachlorosthens)	-	Lend and cofficients
	Chlorosityi ethers (chloromethyl, chlorosityi,	45	
	and mixed others)	44	Negletiniano
	Chicristed rechibers	47.	
	Chicrimated phenois tother than those listed	44.	Mirobenzene
18.	elegisherik includes Pichigraphendis and	44.	
	chiorinand crumis)	48.	Nitreprenois (including 2,4-dinitreprenoi, dini- tradinaci)
19.	Chioreterm	50.	
			Mirgagorona
	2-Chlorophenol		Principle Communication Commun
	Cironnum and compounds	27	
	Cooper and correcting		
	Cyernden	54.	
	DOT and metabolities	54.	· · · · · · · · · · · · · · · · · · ·
	Dichleroperatures (1,2-, 1,3-, and 1,4-dichlero-		DemocrativeCornes, Democryremen, Democrativ-
			Crambiana, Chrysones, Characterstracenes,
	Dichloroburgidine		and Indentifyrenes)
	Challerostylenes (1,7-and 1,2-dichlerostylene)		Selection and components.
	2,4-Cichiarupnenai		Sher and compounds
23.	Clichicropropene and dichicropropene		2.1.7.5-Tetrachiurusburus o desin (TCDD)
	2.4-Climathylphenoi		Tetrachieresthytene
	Districtions		Theillum and compounds
	Closenyinydrazone		Talune
	Endocultan and metabolitae		Tomphene 84. Viryl chloride
34	States and metabolities.	. 🕰	Tricharactiviene 46. Zinz and compounds
•	Project of the constitution of the figure	· 	.
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billion (ppb) level using computer controlled GC-MS. Therefore, 10 ppb was suggested as a reasonable level to analyze for in industrial effluents.

Analytical minimum detection levcis for many penucides aiready existed in the Federal Register, so it was suggested that those standard methods and detection levels be used to anxiyze for pesucides and polychiorinated biphenyis (PCBa). However, a problem still existed with the concept of analyzing for so many classes of organic compounds in the Toxic Pollutant List. The chailenge of chemical analysis of a sample for literally thousands of components is staggering-especially when these components may be at part per billion levels in a complex sample matrix. The expenditure of resources in government as well as private laboratories would be overwheiming if analyses were attempted for all possible chemicals on the original list of compounds and compound classes.

In order for contractors to be able to submit costs for conducting analyses, they had to at least have a finite list of compounds to be analyzed for. Therefore, a second meeting was held a few weeks later in Atlanta to resolve the Consent Decree Toxic Pollutant List into one that was contractually and analytically manageable.

In addressing the 13 metals on the Toxic Pollutants List the term, "... and their compounds," was interpreted to mean "total metals," which would include both inorganic and organometallic compounds. The standard method for analysis of total cyanides was selected and asbestos methodology was deferred until later. This left a list of 50 categories of organic pollutants, Not counting PCBs, toxaphene, and chlordane, there were 18 groups of

organic pollutants, each containing 2 to 50 compounds. To resolve these groups into a list with finite proportions required decisions that addressed the Consent Decree.

Four criteria were employed to prioritize and select specific representative compounds for each group. This provided the required specificity necessary for developing analytical methods and for contract management without excluding other compounds in those classes that may be of future concern.

All compounds specifically named in the Toxic Pollutant List (Table 2) were automatically included. The availability of chemical standards for verification and quantification was considered mandatory. Therefore, every representative compound added had to be listed in at least one chemical supply catalog.

TABLE 3
EPA list of 129 Priority Pollutants and the relative frequency of these materials in industrial wantewaters.

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				•	
		31 are proposite			
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2.7	10	Addytenation	1.0	5	1.3-Children was a second
28.1	25	Corpora	34.2	25	Madintone entertain
23.3	. 2	Tehuma	1.9	•	Martin areares
16.7	34		0.1	1	Adopting terrorising
7.7	14	Cartan tomorrate	1.9	12	Denistra .
5.0	10	مسبسیانی	4.3	17	This is the contract with the contract of the
4	16	1,3- 010/40/40740-4	C.S	11	Trichtereiterentenen
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1.4		1,1-Clahimuntan	2.5	16	Chieffermannellang
7.7	17	1, 1-Charles watering	10.2	19	Terrestriare
1.9	12	1.1,2-Tri chistorian	10.5	21	Trightermorphone
4.2	13	1,1,2.2-Terransurassuras	0.2	2	Virtyl grupring
0.4	2	Chippellure	7.7	18	1,2-White-Old Herosthylane
1.5	1	2-Chierostiyi velyi other	0.1	2	teri@dramentys prime.
40.2	28	Chipmin			
		46 are hase/hours extracts	-		
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4.0	•	1.3-Cloris-viscous	7. 2	12	Pullinguage
		1.4-010-10-10-10-10-10-10-10-10-10-10-10-10	5.1	•	Chrysons
2.5		Historia	7.8	14	Pyroper
قــة	i	Harmania Character	10.6	18	/ Promoutrons
1.1	7	Hampital Table Table	10.0		Ampress
1.0	4	1.2.4-Trialismosaurus	2.3	•	Bertinsportvenere
0.4	3	that2-Chimpethany makes	1.9	•	Bermatillerarriera
10.6	18	Negration	1.8	•	Bernatik Pharmatikara
9.6	i	2-Chierman de la company	1.2		Burunggyrane
1.5	13		0.8	4	Printed 1,2,3-4,650
1.8	9	Hiratoropo	9.2	4	Otherstee Alecter
1.1	3	2.4-Cintromer	0.6	7	Bernarie A. Dog Viene
1.5	•	2.9-Company	9.1	2	4-Charaghanyi ghanyi
0.04			0	•	offer 1.2'-Cignorysanguina
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ü	12 15	Di-A-cetyl professor	1,1 0.8	7	biol 2-Chioreadiyil other
7.9		Chromyi girthanan Chattel andressa	0.1	,	1.2-Olphonyinydraumu
18.9	20 23	Of-o-budyt graftmane	1.2	Ġ	Mendeling way distributions in the North Address and the International Conference on the Inter
10.7	43	Contracts brangering	1-2	3	

Frequency of occurrence of the representative compound in water was an important consideration. All compounds except those named in the Toxic Pollutant List were considered if they were found with a frequency of 25% of the total known listings for that class of compounds.

 Chemical production data were used as a guide for prioritizing choices when they were available.

A draft manuscript of an EPA report listing all known organic pollutants (other than pesticides) identified worldwide in water through June 1976, was used for the criterion of whether a compound was a recognized water pollutant (Shackelford and Keith, Frequency of Organic Compounds Identified in Water, EPA-600/476-062). Ten organic chemical catalogs were searched to determine whether chemical standards were

commercially available.

Finally, Stanford Research Institute's "1976 Directory of Chemical Producers, USA," and Radian Corporation's "Organic Chemical Producers" Data Base Program" were used to gather data concerning manufacture of various candidate compounds. A list of 123 materials was finally compiled and submitted to the christonnian plauntiffs in the Consent Decree. At their request, five additional Aroctors and di-n-octyl phthalate were added to raise the total to 129 (counting the Aroctor mixtures, chlordane, toxaphene, and asbestos each as a Priority Pollutant).

Table 3 summarizes this fist and also indicates the relative frequency with which these compounds are being found in industrial wastewaters.

Once the Priority Pollutants were defined as a finite list of materials it

nation of the property of the property of

was possible to develop a sampling and analysis strategy:

- metals
- · 12 pezios
- · total cyanides
- pesucides
- compounds extracted under
- compounds extracted under aikaine conditions
 - · neutral extractable compounds
 - · total phenois
 - · purgesbie compounds

Because of their availability, it was decided to use standard pesticide methodologies for the analysis of pesticides and their metabolities. This usually involves extraction. Florisif column cleanup of the concentrated extract and gas chromatographic

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	<u></u>				<u> </u>
4.4	12	Actingtoniene	Q. 1	1	H-Milyanadanadayanaya
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น	11	2-Miraphanel	. 23 33 44	10	2-Chlorophonoi
2.2	•	4-Miraghanal	` 33	12	2,4-Clattereptone
1.6	•	2,4-Cintrophysia	4.6	12	2.4.6-Trichtersprenne
1.1	•	4,6-Challes-a-wassi	5.2	15	2,4-Olmotrytenes
4	18	Periodiarephone	•		
		25 are post	Manufacture PCT's		
ده	3	a-Britanitas	ده	3	Magazation
0.4	4	3-Enterwine	0.1	ī	Hammarian assesses
22	2	Enteredan matern	0.2 0.2 0.8	4	Hopesarter epones Chiertone
0.6	2 4	а- в +С В-в+С	<u> </u>	2	Tanaphune
0.8	•	β-m·C	<u> </u>	ž	Areas 1016
0.2	4	i-a-c	4.5	ī	Areas 1221
0.8	4 3 5 3	7-84G	0.5 0.9	2	Arester 1232
0.5	\$	Aldrin	0.8	ā	Areser 1242
0.1	i	Clearin	0.6	2	Arteur 1246
0.04	ĭ	4.4-008	ũ	3	Arean 1254
0,1		4.4-000	ü	ĭ	Areas 1290
2	2	4.4-00T			2.1.7.8-Torresterustures
	-			_	p-distant (TCCC)
. 0.2	3	Emirin			
9.2	2	English and proper			
18.1	20	12 000		_	*******
19.8	19	Additionary	34.7	25	Maranary Mathan
14.1	16	Artegras		27	Salaman
30.7		Saryings.	14.9	21 25	Salaman
	25	Beryahum Castinum Cirumana	223	7	Silver Theman
\$2.7	28		18.2	19	
3.36	28	Compar	. 54.6	28	Zec
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analysis, using an electron capture detector. Since there were few basic compounds, this group was combined with the neutral compounds. The acid extractable Priority Pollutants include only phenois. The remaining organic compounds, with the exception of acrolein and acrylonitrile, were readily purgeable from aqueous solutions. The latter two were analyzed by direct aqueous injection GC-MS.

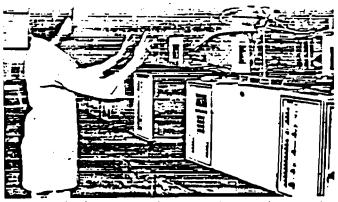
There are three phases of analyses involved with the Priority Pollutants. The initial work is referred to as the "Screening Phase." Its objective is to define which of the Priority Pollutants are in the treated and untreated wastewaters of each of the industrial categories. The second "Verification Phase" is to desermine the efficiencies of the various treatment technologies under consideration. The final "Monitoring Phase" will be used for compliance monitoring of state and federal discharge permits.

me**s**ning. http://doi.org.

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A semiquantitative analysis by GC-MS is all that is required to achieve the objective of the Screening Phase. Three characteristic fragment ions were chosen for each compound and chromatographic methods were devised that would allow unambiguous identification of each compound (with few exceptions).

Tom Bellar and Jim Lichtenberg, at EPA's Environmental Monitoring and Support Laboratory in Cincinnati. Ohio, had been investigating a purge and trap method for analyzing very volatile organic compounds in water. and this technique was applied succonstully to 29 of the Priority Pollutants. The late Ron Webb, at EPA's Environmental Research Laboratory in Athens, Georgia, had been investigating liquid-liquid extraction and VERTOUS CONCENTRATION MELHODS for isolating intermediate volatile organic compounds from water: these techniques were applied successfully to 57 of the Priority Pollutants. Eleven of the extractable compounds are phenois extracted under acidic conditions with methylene chioride, and 46 are neutral and basic compounds extracted under aikaine conditions with the same solvent. The 26 pesticides are extracted with a methylene chloride-hexane mixture, using a separate aliquot of



Pesticide sentysis. After extraction on oliquet is injected into a gas chromotograph

wastewater. The purgeable sample requires a third aliquot of wastewater collected separately.

The decision was made to use con ventional packed columns for all chromatographic separations even though it was realized that capillary columns would provide superior resolution. Because most laboratories had had little experience with capillary columns, and since the identification and quantifications were to be based on selected characteristic ions within a small retention time "window," was not necessary that complete chromatographic resolution of all or-Priority ERRIC Pollutants

To preciude omusion of other organic compounds potentially included by the classes of compounds in the Toxic Pollutants List, all GC-MS data are being committed to permanent storage on magnetic tape. Likewise. the organic extracts are being sealed and stored at subzero temperatures at the Athens, Georgia, Environmental Research Laboratory. These extracts and GC-MS tapes make up the most extensive and representative crosssection of data on organic compounds in industrial wastewaters that has ever been computed. These will be examin further for additional compound identifications over the next several

Water samples for the purproble compounds are collected in 40-ml, glass vials with Teflon-lined septa. The vials are completely filled so no bubbles are present. Usually 5 ml. of this sample, spiked with bromochloromethane and 1.4-dichlorobutane as internal standards, is used for the analysis. After being transferred to a glass spurging tube with a fritted-glass bottom, the sample is purged with helium.

The volatile organics are stripped

from the water and adsorbed in a stainless steel trap packed with Tenax-GC and silica gel. At the compietion of the purging step, the gas flow to the trap is reversed and the trap is rapidly heated to 180 °C. The organics are thermally desorbed from the trap to the head of a gas chromatographic column held at room temperature. When desorption is complete the chromatographic column is temperature programmed and the organic compounds are eluted into a computer-controlled mass spectrometer where they are identified and quantified. Initially acrotem and acrytomunic were analyzed by direct aqueous inction, but as of September 1978, the EPA has authorized an optional analysis using the purge and trap technique.

Problems with the Screening Phase methods that have not been resolved

- Several compounds required about 200 ng instead of 40 ng for minimum detection.
- Phenanthracene and anthracene are indistinguishable.
- 1,2-diphenyihydrazine decomposes to azobenzene and Nnitrosodiphenyiamine decomposes to diphenyiamine.
- N-eurosodimethylamine grees
 broad low chromatographic
 peak.
- Direct aqueous injection of acrolein and acrylometrie suffers from low sensitivity and the purging efficiency for these compounds is variable.
- In spice of these difficulties the Screening Phase Protocol is successful for the great majority of the Priority Pollutants.

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Analysis of total cyanidas is by the standard colorimetric method. After the standard colorimetric method. After the standard colorimetric method. On several hours and hydrogen cyanida is cohered in an attaines colered. Absorber is mensured at \$75 nm in the pyridine solution produced by adding pyridine and berbitums acid. Total phenote, for the purpose of clanity, are those compounds that are mesured by Water samples for total phenots are Water samples for total phenots are collected in glass bottles, acidified to collected in glass bottles, acidified to

Total Cyandes and Pennsel, Altzline preservation at 2 pirl of 12 or greater is necessary for the cyandes when the sampies are collected. Again, these preservation requirements run aloud of DOT airfreight regulations. Interestion, these sampies are now ahipped by surface transportation. They must be analyzed within 24 hours of receipt at the laboratory.

are shipped unpreserved, acidified uppreserved, acidified uppor receipt at the laboratory, and are held for one week proc to analysis.

The samples are collected in pleasuc constants and organish were presented with nitror acid before ship-inneast (OCT) regalations prohibit shipping surre acid by air in prohibit shipping surre acid by air in prohibit shipping surre acid by air in precises has any concentration so this practice has any concentration so this practice has any concentration as the practice has any concentration.

musmpui IS lis 10) alli grab destity assertance program and the developed and maintained both the of surveys. This regional laboratory DOWN MITTER FOR GALL & AMPLION. DESCRIPTION AND PROPERTY OF THE PARTY TO INCRETINELY-COMPINED PRESENT TITION the Chicago Regional Laboratory had TOUT THE SISTIEUR STEING JOJ AJOTE בשנים שנושים בשום וסג מחויבושם סטפ tral Regional Laboratory in Chicago. are being analyzed by the EPA Cenanalyses from the Verification Phase Pass and a large number of metals have betrormed during the Screening The Nerals. All of the metals anal-

make errors than a human. periods of time and is less likely to Buoi Jano Succious) antitudal snorpo) Summarier does not tire of performing routing analyses. Furthermore, the to do what will eventually be they do not use bighly trained people PULETIZED SEELYSEE PROSE COSE STREETIVE. in the near future. Not only are combounded or mas company, bothware evaluate the performance of the most coming trend. Like EPA intends to proved methods, are obviously the ortey Pollucants, while not yet apcometed GC-MS analyses of the Pri-Untion level greater than 10 ppb. Au-COMPARET IDEBLIFICATIONS ST & CONCERN-SYLEGON-BRIES 4PMO.0 bits SYLHEDG-BRIES 4500 data points revented only 0.13% Statistical analyses of more than

to achieve the same results.

Names processing takes 3 to 4 hours within minutes.

Manuelless them within minutes.

Computer-controlled GC-AC analyses lend themselves to computer-essisted analyses and several aboratories are developing various factories are developing various degrees of automated analyses. Hadden for example, has an automated software program that analyses the mass spectral data and, on the bases of fragment one and their correct ration, refative retenuon times, ion internal stanscenuos relative to the internal stanscenuos and response factors, completely dark and response factors, completely

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The Extractables, Two inters or water from a 3-day composite sample be made strongly alkaline and extracted with methylene chloride. The extracts are concentrated in two concentrates are concentrated in the concentration and second a micro-concentration and second a micro-concentration and second a micro-concentration of dig-anthracene is added to the 1.0 of mater is from made strongly acidic and reextracts with methylene chloride.



Tentative monitoring phase methods

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pH 4 with phosphoric acid and chilled. These samples can be shipped by air and they must be distilled within 24 hours after receipt at the laboratory. 4-Aminoantipyridine is added to the distillate and the resulting dye is extracted into chlorotorm and its absorbance is measured at 460 nm.

Ashestos. Since there are many types of asbestus the first problem was how to define it. Asbestos was defined finally as "fibrous aspestos" and consists of chrosottle. To isolate the fibers. water is filtered through a Nuclepore filter and the retained particulates are carbon coated under vacuum. The orgame filter is dissolved with chloroa carbon film. A portion of the film is magnified 20 000 times with a transmission electron microscope, and the asbestos fibers are identified by selected area electron diffraction. A representative area of the electron microscope and is counted, and the concentration of asbestos in millions of fibers per liter can be calculated from the size of the water sample.

Protocol Reviews. Periodically representatives from EPA, industry and the contract laboratories meet to review common problems, new analytical techniques and the status of all programs. These meetings have provided an excellent forum for the shared expenence of the chemists involved in these analyses. In many, if not most cases, split samples are provided to the industries involved so comparisons of the data and the methodology can be made. To date no fewer than nine industrial work groups have made important contributions to the ever continuing review and retinement of the analytical protocol.

The Verification Phase is designed to provide a basis for developing new source performance standards, pre-treatment standards and 8AT regulations. Plants within an industrial category are chosen to encompass various treatment technologies and wide geographic areas. In general, only Priority Pollutants identified during the Screening Phase are reanalyzed in their respective industrial categories in this phase.

Conventional pollution parameters (for example, BOD, TOC, and pH) are also measured along with the Priority Pollutants. The sampling and analytical methods are varied and depend on the chemical process treatment technology being evaluated and the parameters selected for verification. Analytical methods may include those in the Scruming Phase protocol, only GC using packed or capillary columns and specific detectors, high

pressure liquid chromatography (HPLC), or any combination of the above.

The Monitoring Phase will use less expensive methods than GC-MS whenever possible. Five contracts, totaling \$1.5 million, are aimed at developing and verifying alternate methods to GC-MS for analyzing the organic Priority Pollutants. These methods concentrate on sample cleanup and fractionstion prior to analysis. Final identification/quantification will be done using GC and HPLC with specific detectors.

The 114 organic Priority Pollutants are divided into 12 groups (Table 4). and methods are trying to be developed that will specifically identify and quantify each of the Priority Pollutants in that group in the presence of interfering organic compounds. To verify the methods, wastewaters socked with solutions of each of the groups will be analyzed. Youden pairs of concentrates (two solutions with close but different concentrations) will be used for spiking. Twenty EPA and private laboratories will verify the majority of the methods for all 12 groups before the end of 1979. The EPA will not necessarily be bound by the methods developed for these 12 groups. Hopefully some unification will be achieved by taking the best features of methods developed under these contracts and also under some EPA drinking water analyses contracts. Obviously methods developed for drinking water analyses cannot be used for industrial wastewater analyses without modifications to cleanup procedures. But fewer permutations might be achieved using some of the superior cleanup methods developed under Monitorine Phase contracts and some of the superior chromatographic conditions developed for analyzing drinking water samples for these same compounds.

A first draft of the methods for the monitoring phase will be promulgated this month.

The first draft of each method was due in December 1978. Starting about that time will be a series of intertaboratory studies to verify accuracy and precision of each method. If a wastewater contains Priority Pollutants in more than 3 or 4 of the 12 groups, it may be more cost effective for a discharger to self-monitor for them using GC-MS. Ultimately, there will probably be some industrial categories that are served best by GC-MS analyses for self-monitoring, especially in view of

the potential new software programs that automatically perform the identifications and quantifications.

With the undertaking of the Priority Pollutant program, the EPA has taken its first step on the long road of using organic analyses for monitoring toxic chemicals in industrial discharges. The Priority Pollutant program is, for the first time, establishing a baseline of information with regard to chemical discharges from industrial point sources. Together with the expanded program covering some 40 publicity owned treatment works (POTWs), an overall picture of the nation's ambient and source discharges is being provided.

The 129 Priority Pollutants are only the beginning of a better way to monitor industrial wastewater discharges. The mass spectral data tapes and the stored extracts have yet to be examined. Programs to work with this data will be initiated before this year is out. Through these efforts a further list of compounds may be developed which are of concern to industry, the EPA, and encironmentalists.

Perhaps the computeds that are infrequently found can be removed from the toxic pollutant list and others more deserving be added. The methods, of course, will continue to improve as technology advances. A larger and more valid data base will be accumulated. In the end we should have reasonable cost-effective methods for reducing industrial pollution and monitoring for it. And, after all, that is what we started out to do—nobody thought it would be easy.





De, Larry H. Keith (1) is manager of the Analytical Chemical Discission of Radian Corporation on Australia. Texas, the is also Chairman of the ACS Dission of Empressional Chemister and profer to priming Radian, worked for EPA at the Athens, Georgia Environmental Research Laboration

William A. Telliard (e) is chief of the Energy and Mining Branch. Effluent Guidelines Dicision. Entironmental Protection Agency. Proor to his present position, he marked in the Office of Waser Enforcement, both in the Permiss Diessian and the Enforcement Dioissian. He juneal the agency in 1972.

Volume 13, Number 4, April 1979 423

APPENDIX C

RADIOMETRIC DATA

APPENDIX C.1 DATA FROM ONSITE SURVEY

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ANALYZED DATE ANAL	BY DL, SPEED YZED 915 (84	Rockwell Emply System	ma Group	DATE SAMPLI	·····································
FILM NO. —	100 HOT WATTE IN THIS 804)	HEALTH AND SAFET	Y ANALYSIS REPORT		COMMO LEHR
SAMPLE NUMBER	DES	CRIPTION AND LOCATION	Glass-	BESULIS	·
61	Hde # 18 41	deep	9479	3	
62	Hde # 22 C		12341	1	
63	Т		10944	2	
64	. 45	s' deep	9260	3	
CE	Hole # 260 C		13607	1	
66	· T	-	12818	2	
67	4,5	'deep	18201	3	
68	Hole # 25 C	•	7716	(
69	T		9102	2	
70	વડ	deep	9801	3	
71	Hde# 288 c		8320	11	
72	10	os	8934	2	
43	51	dexp	10603	3	
74	10'	deap	6842	4	
35			12107	5	
76		deep	12203	_ 6	
77	Hole # 27 C	·	6715		
71	T		7619	2	
79	5		10994	3	
80	<u> </u>	deep	11062	4	
COMMENTS	Ludlum 2000 .	f Eljavline 2x2 ILI	xtal	-1	SOIL WATER AIR _
	-			SMEAR OTH	ER Apos Finner
				TYPE OF ANALYSIS:	0 0
LEDGER	CONTRACT	SUB-	WORK	RADIOMETRIC	S BERYLLIUM
ACCOUNT	OR ORDER		RELEASE	- OTHER	(IOCHTIFT)
LOG BOOK	(NO PAGE	-			

DAIS AMPLE DESCRIPTION AND LOCATION CARESTY ANALYSIS REPORT RESULTED CARESTY	DATE ANALYZED BY D.C. SPEED DATE ANALYZED 9 5 8	* **	well International	SUBMETTE	DBY FAIB/I	k? Bil
Namile DESCRIPTION AND LOCATION CPM REVAILED	I EU M MO					
81	I I DESCE	IPTION AND LOCATION	ciross com			
83				. S		
10	83 Ide # 12 C		\ \(\omega \)	1 2 2		
15	85 5'		11029	3		
81 Hole # 13 C 6346 1 90 T 7251 2 91 S1 12348 3 92 9' 7 7 36976 4 93 10' 7 31006 4504 94 15' 16371 5 18860 6 76 Hole # 14 C 7842 1 47 T 10831 2 47 T 100 Hole # 10 C 7837 3 100 Hole # 10 C 7537 1 COMMENTS: Lud un 2000 + Ebraline 2×2 IDT ×10 1 LEDGER ACCOUNT SUB- WORK RELEASE 01HER 1886 11 1 LEDGER ACCOUNT RELEASE 01HER 1886 11 1 1011ER 18860 11 1 117FE OF ANALYSIS: RADICIMETRIC M. BERYLLINIM 01HER 18860 11 1 12348 3	97 5'		12136			
91			6346	-		
93 100 4 10 16371 5 18860 6 1951 18860 6 18860 6 1 18860 6 1 18860 6 1 1 18860 6 1 1 18860 6 1 1 18860 6 1 1 18860 6 1 1 18860 6 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			12348			
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100 Hole # 14 C	94 15'		16371	5		
3.51 100 Fole # 10 C COMMENTS: Ludium 2000 + Elberline 2×2 kbl ×10l TYPE OF SAMPLE: SOIL WATER AIR SMEAR — OTHER GYTTS GAUSIUM TYPE OF ANALYSIS: RACCOUNT SUB-ACCOUNT RELEASE OTHER — OTHER GYTTS GAUSIUM OTHER — OTHER GYTTS GAUSIUM TYPE OF ANALYSIS: RACCOUNT OR ORDER ACCOUNT RELEASE OTHER — OTHER GYTTS GAUSIUM OTHER — OTHER MANAUM OTHER — OTHER GAUSIUM OTHER — OTHER GAUSIU	96 Hole # 14 C		7892	1		
COMMENTS: Ludium 2000 + Ebenine 2×2 lal ×101 TYPE OF SAMPLE: SOIL WATER AIR. SMEAR OTHER GYPES GAUSIUM TYPE OF ANALYSIS: RATHOMETRIC	48 3.51		₩ 56800	. 3		
SMEAR OTHER STEE	100 Hole # 10 C		7537	1		
LEDGER CONTRACT SUB- WORK ACCOUNT RELEASE OTHER	COMMENTS: Ludium 2000	t Ebaline 2x2 R	AL xlox	1		
LEDGER CONTRACT SUB- WORK ACCOUNT RELEASE OTHER				TYPE OF ANALY	SIS:	
	ACCOUNT OR ORDER					· -

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FILM NO. (DE NOT PAITS IN THIS BOX)	TH AND SAFETY ANAL	YSIS REPORT	BLDG. AND	' L
SAMPLE DESCRIPTION AND LO	CATION	Glass	PESUL ATION	15
101 Hok # 10 T		9901		
102 5' deep	_ 	12240	2 3	
103 10' δερ		10985	4	
101 15 doep		10815	5	
105 , A' deep		11356	6	
10b loe # 9 C		7788,		
107 T		285	2	
10,9 51 deep		1!379	3	
م يحك 10 ا		11097	4 .	
110 15' deep		11286	5	
(11 20'deep		11953	<i>(</i>	
112 Hole # 8 C		7760	l <u> </u>	
	····	8188	2_	
114 3.5 deep		10276	3	
115 Hole # 7 C		8000		
116 T		8657	2	
117 5' deep		10552	3	
(d) C		7572		
/19 T		8न्द्रह	3	
120 5' deep		10400	3 1	
COMMENTS: Ledlum 2000 & Eparling	2 ZXZ HAI Xde	~	TYPE OF SAMPLE	: SOIL WATER AIR
			SMEAR 0	THER GIDES TAMINE
· · · · · · · · · · · · · · · · · · ·	_		TYPE OF ANALYS	is: O
LEDGER CONTRACT SU	B- WORK		RADIOMETRIC	BERYLLIUM
LEDGER CONTRACT SU ACCOUNT OR ORDER AC	COUNT RELEASE		OTHER	(IOCNTICT)
LOG BOOK NO PAGE			L	

ANALYZED BY EH Badgez	nal	SUBMITH	OM TIP	1611	
······- ′	HEALTH AND SAFETY ANAI	YSIS REPORT		D RODANO, LE	dr.
SAMPLE SWEAR BRUCK DESC	CYTTA RIPTION AND LOCATION	Gais Jefila	درجيع تكسدي		100cm2
1 animal Kospital #2-	NW Coner Exhaut Fan	2.	312	0.50	-525
2 " " "	11 t " (1	i	357	IJ,	7,51
3 h 11 #1	Reof Center 11 11		315	Á	- 1.31
4 6 6	<u> </u>	2	343	$\omega, \leq 0$	5.42
	1 11 11 11 11	£	301	- e., ·	5,46
	W Corner HEPA System		545	\mathcal{S}	53.53
- [,]	<u>, "</u> , , , , , , , , , , , , , , , , , ,		316	<i></i>	1.52
	<u>E 1' " " " " " " " " " " " " " " " " " " </u>		3-19	<u>کل .</u>	437
9	<u> </u>	<u> </u>	294	C150	- 1 1 2
	showst Blower - Small		354	3.00	105
11 Inhalf Liquid Fil	Tere - Stand	Ø 3-0°	W 5 2 + 371	· 6, 20	11.77
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11		4	334	(31	4.33
			314	_ <u>1</u>	= 2,70%
10 /		$ -\frac{3}{2}$	329	421-	151
17 Liquid Pum	p W/cler right quage (Flow)		361_	O(5)	10.00
$\frac{12}{15}$ $\frac{\text{Flan'}}{1}$		- <u>3</u>	36.6		د ^۲ با ا
	Eleur	_ 3,	318	7.01	- 1.03 - 1.73
20 11	1)	/	324	4	0.52
<u> </u>	tour Time =	10.0 min		E- SOIL WAT	
BKC EFF			SMEAR _ OTHER		
0.1 5.03 ·			TYPE OF ANALYSIS:		
BCA 31,2 3.58 LEDGER CONTRACT SUB. WORK			RADIOMETRIC BERYLLIUM .		
ACCOUNT OR ORDER ACCOUNT RELEASE			OTHER		
L OG BOOK NO PAGE			<u></u>		

ANALYZED BY _FT Badger Rockwell International Energy Systems Group HEALTH AND SAFETY ANALYS			y Systems Group		DATE SAN	D BY TITE	हमाह छिप
SAMPLE NUMBER	DESCI	RIPTION AND LOCATION		1 ALAM	BETA	ACPIA	SO COME BOTA
771	Imhoff Laboratory	flour		3 3	3260	2.52	1.63
5,5	11 11	4		3	320	1.01	-0.52
23	Main Office + Labore	dory Rn 112			3 55	1.01	8.51
24		1 / /		<u>(c)</u>	359	2,52	9.55
25				!	331	6	2.32
26		V V		Ø	<i>3</i> 32	-0,50	
77		Rm 118 (Lysid	Scint)	- Ø	317	0.50	-1.24
73 28		Cm 123		2	352	0.50	.5.16
79	<i>y y y</i> -	•			295	op .	- ራ .ናነት
30	Cellular Bulgey Lab	- Channe line		/	265	У	14.40
31	Cellular Biology Lab Health Physics Tra	der		3	32	1.01	1.14
)					jj	
/					17		
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				<u> </u>	1	 	
			-		<u>-</u>	- -/	† · <i>)</i>
				 	 /) 	
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17	 			<u>i</u>	1-17-	1-1-7	
COMMENTS	: NIMC ASJ3PC 9	IF COUNT	71116 = 10.0	1:11	TYPE OF SAMPL	F. (OII - WA)	ER AIR
	BYG EFF				- 1	THER lise	
iPH					TYPE OF AHALY		- 11 FT
801						. <u> </u>	N 14.4
LEDGER ACCOUNT	CONTRACT OR ORDER	SUB-	WORK RELEASE		- OTHER		п/м
LOG BOOK					Joiner	(IDEN 11FT I	
FORM 732-A							

1	BY D.L. SPECED YZED 7/6/19	Energy Syste	III International TY ANALYSIS REPORT	SUBMITE DATE SA	MPI ED 28/10	IXS BY
FILM NO		-1			ID ROOM NO	
SAMPLE NUMBER	the # Dipth DE	SCRIPTION AND LOCATION	apa cou	Detre Ris	alda	bee !
	<u> </u>			412	e	10.9
2	5'			389	0	8.3
3	2 T	·	3	344	0.75	<u>₹</u> . §⁄
4	2 5'		2	383	0.23	25
5	2 20'		$\dot{\omega}$	433	1.13	_ /3, ≠
6	4 T			473	1.35	18.0
3	4 5'			383	0.23	2.5
	5 T			318	0.23	6.2
9	7 T			432	e .	13.4
_10	6 5'		4	362	0.68	5 <u>U</u>
(L	6 T		/	475	Ø	18.3
12	5 5	Aluninum foi T	4	339	0.48	2.3
13	8 5'	Photic bags	.3	339	0.45	9.7
14	8 4'	7	2	4113	0.13	11.0
15	8 7		Σ	380	0.23	7.1
16	7 51		2	383	0.33	7. 5
17	9 15'		3	3960	0.45	9,0
18	1 10'		7	4116	1,35	11.7
(9	9 5'		2	373	0.23	8.7
20	9 TOP		2	357	0.23	4.5
COMMENTS		Grum Samples -	10 min conts	TYPE OF SMALL	I SOIL K. WAT	ER AIR
	a Blyd olym			SME AR	OIHER	F 221 . 1
	By Bhyl 31.9 c/m	JR. L. 2.6		TYPE OF ANALY		
				. RADIOMETRIC _	X BERYLLI	UM .
LEDGE R ACCOUNT	CGRIPACT OR OPPLE	SUB- 	WORK RELEASE	OTHER	(intriter)	
LDG BOO	K NO PAGE			<u> </u>	(IDE=1147)	
FORM 732-A	REV. 678					

ANALYZED BY DATE ANALYZED 9 6 8	Rockwell International		THAMILE NAZ 31AG	$\hat{\mathbf{a}} \mid \hat{\mathbf{h}}_{r}$	184	
DATE ANALYZED 9 6 6	HEALTH AND SAFETY ANALYSIS	REPORT			IIR	
SAMPLE DESCI	RINION AND LOCATION	: :	f RISI	, ~ ∱∙ <i>≱</i> ~~~ ≤ ₩		
HOWBER HOK IT DOOLY	164S	alpha	beta	2/10	WG	
21 9 20 = 1			428		/2,8	
22 10 Top			318	<u> </u>	6.9	
23 10 5"			413	<u>.</u>		
24 10 10 FT 25 10 15-FT		\	40) (2)	e	10.5	
25 10 15-55		4 2	424	0.68	13.9	
26 10 20FT			449	0.23	15.5	
27 11 Top		ļ	410	- o -	15.2	
28 11 5		<u> </u>	357	8	10, 7	
29 11 10		7	421	0.23	7.5	
30 11 15'		2	401	0.23	12.7	
31 11 20		5	436	0.23	11.2	
32 12 Tap		·\	316	0.90	13.7	
33 /2 5'		 	349	8	7.8	
34 12 10'		J 7	730		9.4	
35 12 15'		·	470	1.13	130	
36 12 20'	_	$-\frac{1}{3}$	399-	0.45	9.4	
37 /3 Tap		- 	483	$\frac{0.93}{1.13}$	19.2	
38 13 51		5	481	·	19.0	
39 13 10'	Bones	1 3	442	0.50	14.4	
40 13 15'		`	 	<u> </u>	L	
COMMENTS:				LE: SOIL 📐 WAT		
NWC				SMEAR OTHER		
	•		TYPE OF AHAL			
LEDGER CONTRACT	SUB- WORK			BERYIII	UM	
ACCOUNT OR ORDER	ACCOUNT RELEASE		- OTHER	(IDENTIFT)	_	
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SAMPLE HORE #		AND LOCATION	[gross co	DOME RE	alder	Tuta		
41 13	20'			1	415	0.48	10.9		
42 14	T.,p			(c)	412	1.13	10.9		
43 14	_5",			3	395	0.45	8.9		
44 18	Top			2	445	0.23	14.4		
45 18	51			. ?	403	0.23	4.8		
46 20	Top			4	361	0.68	4.9		
47 19	5'			· , · · ·	448	0	15.1		
48 17	Top			4	433	0.68	13. ±		
49 20	5-1			<u>L</u>	406	<u>.e.</u>	10.2		
50 20	/0'		· · · · · · · · · · · · · · · · · · ·		419	0.75	<u>//. 7</u>		
5/ 20	151	_		<u> </u>	471 3 <u>8</u> 1	e e	7.3		
52 20	<u> یو'</u>			<u> </u>	388	.6	178		
53 21	Tep	· · · · · · · · · · · · · · · · · · ·		!	310		8./		
51 21	5-)			3	425	<u>8</u>	\$7.3		
55 22	Top			<u>_</u> ;	451	0.45	12.4		
56 12	5'		-		398	0,23	9.6		
57 23 58 23	<u>Tep</u>			<u> </u>	421	0.9	9.3		
59 23				<u></u>	455	0.23	15.9		
40 24	Τορ			-	456	0,68	153		
COMMENTS: 1)MC			10 Mih	witz	 	PLE: SOIL X. WA	TEO AID		
DIVIDE L						OTHER			
					TYPE OF ANAL		Chilly !		
				·- ·· ·· · · · · · · · · · · · · · · ·	1	BERYLL	IUM		
LEDGER ACCOUNT	CONTRACT OR ORDER	SUB- ACCOUNT	WORK RELEASE		OTHER				
LOG BOOK NO	PAGE				į.	1101=11771			

ANALYZED BY D. L. SPECP DATE ANALYZED 916 84 FILM NO	Rockwell Energy System HEALTH AND SAFET	Y ANALYSIS REPORT	DATE SAI	ID ROOM NO	125 184 HR
SAMPLE NUMBER HE DEN DESC	ERIP HIM AND LOCATION	alpo	bele	alpha	bet
61 24 51			443	0.45	14.5
62 24 5'	eff of auger tip		425	0.45	12.4
63 25 Top 64 25 5' 65 26 Top 66 26 5'		-	453	e	15.7
CH 25 5"		2	45पू	0.23	15.8
65 26 Top		4	418	0.68	11.4
		2	4/35	0.23	13.6
67 27 Top			- 428' -	0	12.8
160 127 51			439	6	14.1
6 27 10' 70 27 15'			400	er	10,2
70 27 15'		2	430	0.23	15,2
7 27 20'				0.68	130
	Run into Cobles		435	0.68	136
	<u> </u>	$ \frac{1}{2}$		<u>u</u>	109
14 18 B Top	· 		414	0.23	
75 28 5		2	436	1./3	13.7
76 1813 10'			434	0,23	/3. \$
78 288 15			458	0.45	163
- 48 138 30'		3	390	0.45	8.3
19 29 Top		3	455	0.45	15.9
				<u>v</u>	11.6
COMMENTS:	_	Duin counts	TYPE OF SAMPL	· · · · · · · · · · · · · · · · · · ·	ER AIR
UMC 1633PC =			MEAR	OTHER TIBE	
<u> </u>			TYPE OF ANALY		
LEDGER CONTRACT	SUB	WORK	RADIOMETRIC .	L. BERYLLI	UM
ACCOUNT OR ORDER	ACCOUNT	_ RELEASE	OTHER		
LOG BOOK NO. PAGE			L	<u> </u>	

FORM 732-A REV. 6-78

ANAI YZED	BY DL. SPECED YZED 9/6/84	Rockwell Internation	si	SUBMIT I	MPLID 8/10	(R) S
FILM NO	(00 NOT WALLS IN THIS BOIL	HEALTH AND SAFETY ANALY	YSIS REPORT	BLDG A	UD ROUM HO. LE	H12
SAMPLE NUMBER		RIPTION AND LOCATION	300 G	peter	alpha 1	jean.
181	29 10'		2	338	0.23	7,2
1821	29 15"		3	425	0.45	12.7
83	29 20'		<u>3</u>	40 }	0.45	10,3
84	30 Top		_ 3	378	0.45	4:9
85	30 5'		\ \ \	438	8	. 23 9
80	30 /0'		\ <u>5</u> ,	385	0.90	7, <u>7</u>
- 8t	30 /5-1		2.	456	0.68	12.5
00 00	30 20' 31 Tep		<u> </u>	39b 341	0:23	2.6
20 App 15 30 A	31 5'		x:	388	1.13	8.1
91	31 10'		7	434	1.35	13.5
92	32 T.p		3	312	0.45	6.2
93	32		7	434	1.35	135
)
<u> </u>						
		Total d/m 2306.7 79		 	-	-X
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 -/-	 	ane 24.8 8.28		-{ <u></u> }	- ·	}
		<u> </u>		t		- +
COMMENTS	: NMC			TYPE OF SAMP	LE SOIL WAT	IER AIR
		<u> </u>			OTHER	
<u> </u>		<u> </u>		TYPE OF ANAL	YSIS:	
LEDGER	CONTRACT			RADIOME TRIC	<u> </u>	IUM
ACCOUNT				DTHER	(locaties)	
LOG BOOK				L		

ANALYZED BY D 1 SPECE Rockwell International Energy Systems Group FILM NO. HEALTH AND SAFETY ANALYSIS	REPORT	SUBMITTE DATE SAL	mla	7765 184
SAMPI Rebr to figue for simple point locations	Syste Co	VNE RES	III PA PC	
1 1/7/A11/10/ 19-12/14 1/01/4	alpho_	De to	appa_	10th
9	. 3	467	0.45	11 7
95 10	5	458	0.90	. 13.8
196 11	<u>Ø</u>	40/	.0	9.6
97 12		374	<u> </u>	4.4
1.98. 13	6	385	_8 1.13	_7.2
99 14	4	428	0.68	/ 1.8
L 60 15	6	394	1.13	8.8
D(16	5	422	0.90	12,1
102 17	Ø	4 11	v	10.8
103 18	Ø	452	9	15.6
104 19	4	409	0.68	10.5
105 Hte # 13 Composite	7	4060	1.35	10.2
106 He #13 10' ~	8	524	1.58	34.0
107 Hole #13 10' } Scape Sample @ 10' Composite #164	7	454	1.35	15.8
100 Hale #13 10'	9	448	1.80	15.1
100 Dog Pen 101 Balan Franci DX ACNS	2	440	0 23	14.2
110 / #2 /	2	448	0.23	18.1
112 43	4	419	0.68	447
112 1 144	0	426	No.	/2.5
113 1 45	4	413	0.68	11.0
	117 Con 15		F: SOIL K WAT	ER AIR
		1	DIHER	
		TYPE OF ANALY		acter 1
		1	BERYLI #	1144
LEDGER CONTRACT SUB- WORK ACCOUNT OR ORDER ACCOUNT RELEASE		OTHER		
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FORM 732-A REV. 6-76				

	YZEO	Energy Sys	ell International	DA11 54	APLID 8/8	184
FILM NO		RIPTION AND COCATION Local	TY ANALYSIS REPORT	C/10mm RI	HIS PICUCUM	cs Jyman
NUMBER	Location Depth	Nete	alpha	bota	alpha	botes_
114	Deylor #6 Balan Gra	vel Don Pens		422	alpha 0.68	13.1
1/5	47	7	0	7/5	<u> </u>	1/, 2
110	H &		3	429	0.45	12.8
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COMMENTS	· · · · · · · · · · · · · · · · · · ·	_ 		TYPE OF SAMP	LE: SOIL - WA	TER AIR
				-	OTHER	
				TYPE OF ANAL		[11 / 7]
				1	<u>∠</u> BERYI L	H II.4
LEDGER ACCOUNT	CONTRACT OR ORDER	SUB. ————————————————————————————————————	WORKRELEASE		HOERITET	
LOG BOO	C NO PAGE					

FORM 732-A REV. 6-78

APPENDIX C.2
GAMMA SPECTROSCOPY (CANOGA PARK)

UC DAVIS GAMMA SCANS - SOIL SAMPLES

Soil samples were counted in groups on a shielded, high-purity Germanium crystal. The gamma rays were spectrally sorted according to energy by a Canberra multichannel analyzer Series 85 with built-in computer. The counting times varied from 1,000 sec to 10,000 sec, so in reviewing the data printout, the time of count must be considered. Also, no two samples weigh the same. The scan is for isotope identification only. The Canberra has a built-in resident library. When a peak is identified, it searches the library file of isotopes to try and suggest a possible isotope. When it finds a peak near the one detected, it will print out all possible isotopes according to the list in the memory. The hard copy may indicate an isotope and quantity, but further research would be necessary in most cases, particularly for natural activity, except K^{40} , to positively identify the isotope.

The results of the scan indicate the presence of natural uranium, thorium, and possibly radium and their daughter products. Naturally occurring potassium 40 was of course present also. Traces of Cs^{137} were also indicated, perhaps from fallout. No significant activity other than natural was identified in the samples not sent to an independent lab.

GAMMA SCAN DATA - LEHR

Cample Number		Collection Time (sec)	Total Rel. Activity Cs ¹³⁷	CDD #	K ⁴⁰
Sample Number	Location			ERR %	<u>K</u>
1, 2, 3, 5	Hole 1, top + 5 ft H2, top + 20 ft	2,000	6.7×10^{-5}	15.1	0
7, 8, 9, 11, 12	Hole 49, deep 8, 5 top, 9 top, and 1167	2,000	0	. • • •	2.5 x 10 ⁻³
13, 14, 15, 16, 41	Hole 7 deep; 2 in., 5 ft, 8 plastic 140 11 in.	2,000			2.9 x 10 ⁻³
17, 18, 19, 20, 21	Hole 9, 2 in., 5, 10, 15 and 20 ft	2,000	2.1 x 10 ⁻⁵	80	1.8×10^{-3}
22, 23, 25, 26, 44	Hole 10, top 5, 15, 20; hole 18 top	2,000	0		4.4 x 10 ⁻⁴
27-31 ·	Hole 11, 4 in.; 5, 10, 15, and 20 ft	2,000	2.3 x 10 ⁻³	72.7	1.0 x 10 ⁻³
32-36	Hole 12, 4 in; 5, 10, 15, and 20 ft	2,000			3.1 x 10 ⁻²
37, 38, 40, 41	Hole 13, 1, 5, 15, and 20 ft	2,000	2.5×10^{-3}	66.6	1.6×10^{-3}
45-48	Hole 18, 5 ft; Hole 19, top 5 ft, hole 20 top	2,000	3.6×10^{-5}	23.5	6.8 x 10 ⁻⁴
49-52	Hole 20, 5, 10, 15, and 20 ft	4,000	Trace	Trace	3.4×10^{-3}
53 -56	Hole 21, 5 in., 5 ft; Hole 23 3 in. 5 ft	4,000	1.6 x 10 ⁻⁵	86.6	2.9 x 10 ⁻³
57-61	Hole 23, 4 in., 5 & 10 ft; Hole 24, 3 in., 5 ft	10 ,000	2.3 x 10 ⁻⁵	43.6	8.3 x 10 ^{−€}
62 -66	Hole 24, top; 525; 3 in., 5 ft; hole 26, 9 in., 5 ft	2,000			7.0 x 10 ⁻³
67-71	Hole 27, 6 in., 5, 10, 15, and 20 ft	10,000	2.1 x 10 ⁻⁵	42.8	
74-78	Hole 28B, surface 5, 10, 15, and 20 ft	10,000			
No. 73	Hole 28A, 6 in.	2,000	5.3 x 10 ⁻⁵	20.0	2.2 x 10 ⁻¹
No. 72	Hole 28, 6 in.	2,000			2.2 x 10 ⁻³
79 and 80	Hole 29, 6 in., 5 ft	2,000	5.3 x 10 ⁻⁵	20.0	Positive t
84 and 85	Hole 30, 6 in., 5 ft	2,000			8.8 x 10-4
89 and 90	Hole 31, 6 in., 5 ft	2,000	3.6 x 10 ⁻⁵	23.5	1 x 10 ⁻³
92 and 93	Hole 32, 6 in., 5 ft	2,000			2 x 10-3
94	Dog pen surface samples	2,000	4.6 x 10 ⁻⁵	18.1	2.3 x 10-
95	Surface sample location no. 10 dog pens	2,000	5.7 x 10 ⁻⁵	18.5	2.7 x 10 ⁻¹
96	Surface sample location no. 11 dog pens	2,000	4.6 x 10 ⁻⁵	18.1	1.5 x 10 ⁻¹
Water sample	River discharge, approximately 50 gal/min	2,000	1.3 x 10 ⁻⁵	33.3	0
130-131	Hole 29, deep well, drilling mud	2,000	5.3 x 10 ⁻⁵	20	2.7 x 10 ⁻¹
133	Ashes dug up by gophers; Co-60 field	2,000	0		2.1 x 10 ⁻¹
126-129	Hole 29, 30, 40, 50, and 60 ft mud samples	2,000	3.4 x 10 ⁻⁵	25	2.7 x 10 ⁻¹
121-124	Deep well no. 1; 40, 50, 60, & 70 ft mud samples	6,586			2.3 x 10 ⁻¹
117-120	Deep well no. 1; start to 30 ft in 10-ft	10,000			1.7 x 10
	increments			•	
	Sediment at river discharge	10,000	2.1 x 10 ⁻⁵	43.1	2.4 x 10-
97	Surface sample dog pen no. 12	1,000			1.6 x 10 ⁻¹
98	Surface sample site no. 13, NE corner	2,000	6.5 x 10 ⁻⁵		2.5 x 10
99	Surface sample east of bio lab (no. 14)	2,000			2.6 x 10
100	Surface sample near shop (no. 15)	2,000	1.1 x 10 ⁻⁴	14.0	1.4 x 10 ⁻¹
101	Surface sample front gate (no. 16)	2,000	1.11 x 10 ⁻⁴	13.2	1.6 x 10 ⁻¹
102	Surface sample field drain sump	2,000	8.4 x 10 ⁻⁵	15.0	1.2 x 10 ⁻
103	Surface sample near washdown pad	2,000			2.5 x 10 ⁻¹
104	Surface sample near field drain sump	2,000			1.4 x 10 ⁻
105	Hole 13, soil composite hole excavation	2,000	_		1.6 x 10
	Dog pen samples 6, 7, and 8 stacked	10,000	2.2 x 10 ⁻⁵	42.3	2.5 x 10
	Dog pen samples 1, 2, 3, and 5 stacked	10,000	5.1 x 10 ⁻⁵	19.0	2.4 x 10 ⁻¹
	Hole 20, 27, 28B at 20 ft, California samples	10,000	2.7 x 10 ⁻⁵	55.5	7.7 x 10-

TAG NO. = 123 RIHL-CANRERRA-FH BADGER
ABC# 1 LIVE TIME = 2000 TRUE TIME = 200 PAGE ARC# 1 LIVE TIME = 2000 TRUE TIME = 2003 22 AUG 84 20:36 COLLECTED AT: 19:58:58.0 22 AUG 84

ENERGY(KEU) = 0.20996E-06 *CH^2 + 0.54172E00 *CH +0.59208E01
PEAK STATISTICS = 1.00 HIN MIDTH = 6 MAX MID
AREA BACKGROUND = 3 ZERROR = 1.00
150 IU WINDOW = 3.0 KEV ISO ID LIBRARY = 1 TABLE 1 AGE (DAYS)= 0.87612E01

ROIN 1 FROM 72.0 KEV TO 81.2 KEV PEAK AT 77.2 KEV FUHM= 0.9 KEV
INTEGRAL= 338 RATE= 0.1 CP8
AREA= 122 ERR= 25.4%

B1-207 AT 75.0 KEV = 0.22408E-03 UC1

- ROIN 2 FROM 87.9 KEV TO 96.4 KEV PEAK AT 92.5 KEV FUNN= 0.5 KEV INTEGRAL= 194 RATE= 0.0 CPS ARE A= 12 ERR= >>>>X
- ROIN 3 FROM 183.1 KEV TO 187.6 KEV

 PEAK AT 186.3 KEV FUMM- 1.8 KEV

 INTEGRAL- 134 RATE- 0.0 CP8

 AREA- 30 ERR- 60.02

U-235 AT 185.7 KEV - 0.26029E-04 UCI

ROIS 4 FROM 235.4 KEV TO 242.2 KEV
PEAK AT 239.1 KEV FUMM= 1.2 KEV
INTEGRAL= 224 RATE= 0.1 CPS
AREA= 109 ERR= 19.22

PB-214 AT 241.9 KEV = 0.31044E-15 UCI

- ROID 5 FROM 292.0 KEV TO 299.1 KEV PEAK AT 295.7 KEV FUHM= 0.8 KEV INTEGRAL= 82 RATE= 0.0 CPS
- 6 FROM 335.4 KEV TO 342.4 KEV
 PEAK AT 338.2 KEV FUHM- 3.1 KEV
 INTEGRAL- 74 RATE- 0.0 CPS
 AREA- 34 ERR- 30.21 . R014

CS-134 AT 340.6 KEV - 0.95271E-04 UCI

ROIN 7 FROM 348.9 KEV 70 356.0 KEV PEAK AT 352.4 KEV FUMM= 2.0 KEV INTEGRAL-98 RATE= 0.0 CPS AREA-84 ERR= 13.02

PB-214 AT 351.9 KEV = 0.71423E-14 UCI

```
ROIS 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 511.7 KEV FUNM= 2.2 KEV
INTEGRAL= 70 RATE= 0.0 CPS
AREA= 44 ERR= 25.01
                   NA-22 AT 311.0 KEV = 0.0E00 UCI
CO-34 AT 511.0 KEV = 0.0E00 UCI
CO-38 AT 511.0 KEV = 0.0E00 UCI
SR-85 AT 514.0 KEV = 0.7450JE-04 UCI
RGIS 9 FROM 579.8 KEV TO 584.9 KEV
PEAK AT 584.0 KEV FUNN- 1.5 KEV
INTEGRAL- 55 RATE- 0.0 CP8
AREA- 41 ERR- 21.7%
                    KR-69 AT 565.5 KEV = 4.26776E-38 UCI
                    -----
  ROIA 10 FROM 405.9 KEV TO 414.0 KEV
PEAK AT 410.0 KEV FUHH= 2.1 KEV
INTEGRAL= 49 RATE= 0.0 CPS
AREA= 53 ERR= 18.82
                      XE-135 AT 408.2 KEV = 0.2801E05 UC1
BI-214 AT 409.3 KEV = 0.94225E33 UC1
  ROIN 11 FROM 459.5 KEV TO 667.7 KEV
PEAK AT 662.6 KEV FUHM= 3.0 KEV
INTEGRAL= 33 RATE= 0.0 CPS
AREA= 33 ERR= 15.1%
                      CS-137 AT 661.6 KEV = 0.69362E-04 UCI
  ROID 12 FROM 907.9 KEV TO 915.5 KEV
                  PEAK AT 913.1 KEV FUMM= 1.0 KEV
INTEGRAL= 31 RATE= 0.0 CPS
AREA= 31 ERR= 16.1%
  ROID 13 FROM 1454.4 KEV TO 1463.6 KEV
                  PEAK AT 1462-2 KEV FUHM= 2.3 KEV
INTEGRAL= 105 RATE= 0.0 CP8
AREA= 0 ERR= 0.02
                               AT 1460.8 KEY = 0.0E00
                                                                              UCI
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CHANNEL #				D	ATA			
122			15	12	11	18	12	32
128	20	19	17	32	45	19	13	14
134	10 .	13	12	16	· -		-	
		••		,-				
155				18	13	17	13	16
140	24	15	17	12	10	13	9	15
	••		"	'-			•	
327								9
328		6	7	8	18	16	18	10
136	7	11	é	8	10	, 0	10	
130	′	- ''	•	•				
424	4	13	4	6	17	21	50	48
432	19	6	12	8	18	41	30	70
432	17	•	12	•	10			
528	6	•			-		11	
		2 6	5	2 3	3 2	5 3	11	21
534	9	٥	4	3	2	3		
408	-	•	4	8	8		7	
	3	8				12	/	10
616	5	2	1	3	2	3		
633		1	•	-	•			
		16	2	2 3	2 2	5 3	12	22
440	19	16	4	3	2	3	3	
926								
			•				3	0
928	1	5	3	6	10	11	14	8
934	5	2	2					
1059				•				
		,		2	1	1	1	1
1064	3	4	10	15	9	2	1	2
1972	1							
1107					_		_	
	-			2	2	2	2	1
1112	3	9	14	10	12	5	3	3
1120	1	0	0					
							_	
1204		_	_		_		0	0
1208	1.	2	3	4	5	•	3	1
1214	1	1	2	1	2	1		
1444	0	0	1	0	1	4	1	4
1472	1	5	7	2	1	2	2	
2.3.								
2471								0
2472	0	0	0	0	0	0.	.1	1
2680	2	9	8	6	19	17	16	18
2488	8							

IIC DAVIS SAMPLES 7. 8, 9 .11.112 HOLE LOCATIONS 49DEEP -885 TOP-987 TOP-11 #61OP-12 WS DEEP16 N4 SHALLOU LENR

TAG MO. = 123 RIHL-CANBERRA-FN BADGER PAGE 1 ABCB 1 LIVE TIME = 2000 TRUE TIME = 2003 22 AUG B4 19:46 COLLECTED AT: 04:17:49.7 22 AUG 04

EMERGY(KEV)= 0.2097&E=0& &CN-2 + 0.34172E00 *CN +0.3920BE01 PEAK STATISTICS= 1.00

AREA BACKGROUMB= 3 ZERROR= 1.00

ISO ID UINDQU= 3.0 KEV ISO ID LIBRARY= 1

AGE (BAYS)= 0.81077E01 TABLE 1

ROIN 1 FROM 72.0 KEV TO 81.2 KEV PEAK AT 76.7 KEV FUNN» 1.0 KEV INTEGRAL« 444 RATE« 0.2 CP8 AREA« 174 ERR» 20.12 BI-207 AT 75.0 KEV - 0.31957E-03 UCI

RDJB 2 FROM 69.9 KEV TO 94.4 KEV
PEAK AT 92.5 KEV FUHN- 1.9 KEV
INTEDRAL- 301 RATE- 0.1 CPD
AREA- 54 ERR- 51.62

U-235 AT 185.7 KEV = 0.45585E-04 UCI RGIS 4 FROM 235.4 KEV TO 242.2 KEV PEAK AT 238.4 KEV FUNN= 1.3 KEV INTEGRAL= 333 RATE= 0.1 CPS AREA= 177 ERR= 14.12

ROIB 5 FROM 292.0 MEU TO 299.1 KEU
PEAK AT 295.5 MEU FWHN= 1.9 MEU
INTEORAL= 134 RAIE= 0.0 CPS
AREA= 64 ERR= 26.5X

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PR-214 AT 295.2 KEV = 0.22022E-26 UCI

ROIR 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.6 KEV FUHM= 1.4 KEV
INTEGRAL= 89 RATE= 0.0 CPS
AREA= 47 ERR= 27.6%

CS-136 AT 340.6 KEV = 0.12722E-03 UCI

ROIR 7 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 351.8 KEV FUHM= 1.7 KEV
INTEGRAL= 149 RATE= 0.0 CPS
AREA= 93 ERR= 17.2%

PB-214 AT 351.9 KEV = 0.21328E-26 UCI

#01a 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.6 KEV FUHM= 3.4 KEV
INTEGRAL= 21 RATE= 0.0 CPS
AREA= 32 ERR= 37.5%

MA-22 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROIN 9 FROM 579.8 KEV TO 584.9 KEV
PEAK AT 583.1 KEV FUMM= 2.0 KEV
INTEGRAL= 90 RATE= 0.0 CPS
AREA= 76 ERR= 14.42

KR-89 AT 585.8 KEV = 0.29327E27 UCI

ROID 10 FROM 403.9 KEV TO 414.0 KEV
PEAK AT 609.3 KEV FUMM= 2.0 KEV
INTEGRAL= 100 RATE= 0.0 CPS
AREA= 68 ERR= 19.12

XE-135 AT 408.2 KEV = 0.10855E05 UCI BI-214 AT 609.3 KEV = 0.70538E19 UCI

ROIS 11 FROM 659.5 KEV TO 667.7 KEV
PEAK AT 660.7 KEV FUNN= 0.7 KEV
INTEGRAL= 29 RATE= 0.0 CPS
AREA= 0 ERR= 9.0%

RB-B9 AT 657.7 KEV = 0.0E00 UCI AB-110M AT 657.7 KEV = 0.0E00 UCI CS-137 AT 661.6 KEV = 0.0E00 UCI

ROIS 12 FROM 907.9 KEV TO 913.5 KEV
PEAK AT 911.8 KEV FUNN= 1.7 KEV
INTEGRAL= 50 RATE= 0.0 CPS
AREA= 35 ERR= 25.7%

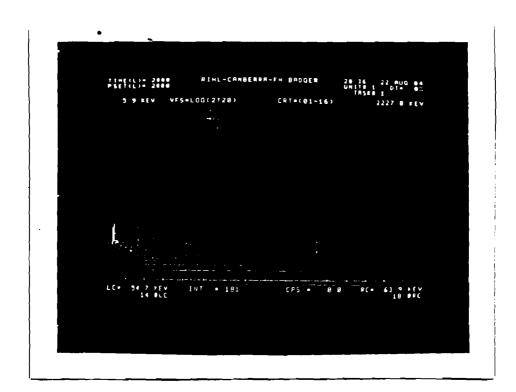
ROIB 13 FROM 1454.4 KEV TO 1463.6 KEV
PEAK AT 1460.7 KEV FUNN= 2.4 KEV
INTEGRAL= 188 RATE= 0.0 CP8
AREA= 62 ERR= 37.02

K-40 AT 1440.8 KEV - 0.24701E-02 UCI

CHANNEL #				0	ATA			
122			18	16	20	21	23	46
128	27	24	40	60	33	28	16	16
134	18	14	10	14				
155				24	24	19	71	40
160	33	31	24	17	20	17	16	15
327								9
328	11	11	10	11	28	29	19	7
336	7	12	6	10				
424	8	10	12	17	27	79	72	39
432	11	13	13	15	17			
528	2	8	5	8	7	18	26	15
536	17	7	4	3	7	7		
608	2	5	4	6	7	12	19	11
61 6	6	2	7	5	3	1		
633		5	3	6	3	22	29	37
.640	17	5	5	4	2	4	7	
926						_	3	2
928	5	7	10	8	7	7	9	3
936	6	3	1					
1059				1	0	1	5	0
1064 1072	18	19	22	8	2	0	4	2
	•							
1107	_		•	5	2	0	3	4
1112 1120	17 1	18	18 5	12	5	5	3	1
	•	•	,					
1206	_	_			_		1	1
1206	5	2	2	1	0	1	2	2
1214	t	0	4	5	0	2		
1664	1	1	2	5	4	9	7	8
1672	2	3	2	2	1	0	3	
2471						_	_	0
2672	0	٥	1	2	1	5	.5	B
2680	13	19	29	22	23	18	18	16
2688	8							

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1



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UC DAVIS SAMPLESIS. 14. 15. 16. 8 41 HOLE LOCATION 7 (DEEP).8(2_IN..SFEET)AND 8 SPECIAL PLASTIC) N14 @ 11 INCHES LEHR

TAB NO. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ABCS 1 LIVE TIME = 2000 TRUE TIME = 2005 22 AUG 84 04:08
CSLLECTED AT: 03:33:05.1 22 AUG 84

EMERGY(KEV)= 0.20796E-06 *CM^2 + 0.54172E00 *CM +0.5920BE01
PEAK STATISTICS= 1.00 MIN UIDTN= 6
AREA DACKGROUND= 3 ZERROR= 1.00
180 10 MINDON= 3.0 KEV ISO 10 LIDRARY= 1
ASE (DAYS)= 0.80766E01 TABLE 1

ROIR 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 77.0 KEV FUMM= 1.6 KEV
INTEGRAL= 336 RATE= 0.1 CPS
AREA= 138 ERR= 21.71

D1-207 AT 75.0 KEV = 0.25346E-03 UCI

ROIN 2 FROM 89.9 KEV TG 94.4 KEV
PEAK AT 92.7 KEV FWHM= 1.9 KEV
INTEGRAL= 194 RATE= 0.0 CP8
AREA= 38 ERR= 69.52

RBIN 3 FROM 183.1 KEV TO 187.6 KEV
PEAK AT 186.0 KEV FWHH= 1.2 KEV
1MTEGRAL= \$36 RATE= 0.0 CPN
AREA= 45 ERR= 40.0X

U-235 AT 185.7 KEV - 0.39044E-04 UCI

ROIN 4 FROM 235.6 KEV TO 242.2 KEV
PEAK AT 238.6 KEV FWHH= 1.5 KEV
INTEGRAL= 235 RATE= 0.1 CPS
AREA= 131 ERR= 16.02

ROIR 5 FROM 292.0 KEV TO 299.1 KEV
PEAK AT 295.2 KEV FUHH- 0.8 KEV
INTEGRAL- 92 RATE- 0.0 CP8
AREA- 22 ERR- 72.7%

PD-214 AT 295.2 KEV = 0.2378E-27 UCI

ROIN 6 FROM 333.4 KEV TO 342.4 KEV
PEAK AT 330.1 KEV FUNM- 1.9 KEV
INTEGRAL- 82 RATE- 0.0 CP8
AREA- 40 ERR- 32.52

C8-136 AT 340.6 KEV - 0.1001E-03 UCI

ROIS 7 FROM 348.9 KEV TO 354.0 KEV
PEAK AT 352.1 KEV FUMM= 1.4 KEV
INTEGRAL= 119 RATE= 0.0 CP8
AREA= 77 ERR= 18.1%

PB-214 AT 351.9 KEV = 0.55472E-27 UCI

RDIO 6 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.8 KEV FWHM- 2.8 KEV
INTEGRAL- 43 RATE- 0.0 CPS
AREA- 37 ERR- 27.02

HA-22 AT 511.8 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

RGIR 9 FROM 579.8 KEV TO 584.9 KEV
PEAK AT 583.3 KEV FUMM— 2.2 KEV
INTEGRAL— 44 RATE— 0.0 CPS
AREA— 30 ERR= 24.62

KR-87 AT 585.8 KEV = 0.44851E22 UCI

ROIR 10 FROM 605.9 KEV TO 614.0 KEV
PEAK AT 609.2 KEV FUMM= 1.8 KEV
INTEGRAL= 73 RATE= 0.0 CPS
AREA= 57 ERR= 17.52

XE-135 AT .608.2 KEV = 0.85951E04 UCI BI-214 AT 609.3 KEV = 0.12435E19 UCI

ROIS 11 FROM 659.5 KEV TO 667.7 KEV
PEAK AT >>>>> KEV FUMM= 655.1 KEV
INTEGRAL= 23 RATE= 0.0 CPS
AREA= 7 ERR= >>>>X

ROIN 12 FROM 907.9 KEV TO 915.5 KEV
PEAK AT 911.0 KEV FUHN= 0.7 KEV
INTEGRAL= 37 RATE= 0.0 CPS
AREA= 22 ERR= 34.3%

ROIS 13 FROM 1454.4 KEV TO 1463.6 KEV
PEAK AT 1460.9 KEV FUNM= 4.0 KEV
INTEGRAL= 126 RATE= 0.0 CPS
AREA= 72 ERR= 23.62

K-40 AT 1460.8 KEV = 0.28485E-02 UCI

CHANNEL E

UC DAVIS SAMPLES 17, 18, 19, 20, \$21 HOLE LOCATION #9(2 IN .5, 10, 15, \$20 FEET) LEHR

*

TAG NO. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ADCM : LIVE TIME = 2000 TRUE TIME = 2001 22 AUG 84 03:15
COLLECTED AT: 02:40:40.4 22 AUG 84

ROIS 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 77.0 KEV FUHM= 1.0 KEV
INTEGRAL= 399 RATE= 0.1 CPS
AREA= 147 ERR= 23.1%

1

BI-207 AT 75.0 KEV = 0.26998E-03 UCI

- ROIE 2 FROM 89.9 KEV TO 96.4 KEV
 PEAK AT 92.5 KEV FUHM= 1.8 KEV
 INTEGRAL= 204 RATE= 0.1 CP8
 AREA= 35 ERR= 65.7%
- ROIS 3 FROM 183.1 KEV TO 187.6 KEV
 PEAK AT 185.5 KEV FUHH= 2.2 KEV
 INTEGRAL= 136 RATE= 0.0 CP8
 AREA= 32 ERR= 57.32

U-235 AT 185.7 KEV = 0.27764E-04 UCI

- ROIS 4 FROM 233.6 KEV TO 242.2 KEV
 PEAK AT 238.7 KEV FUMM= 1.2 KEV
 INTEGRAL= 252 RATE= 0.1 CPS
 AREA= 122 ERR= 18.82
- ROIS 5 FROM 292.0 KEV TO 297.1 KEV
 PEAK AT 293.2 KEV FWHM= 1.8 KEV
 INTEGRAL= 97 RATE= 0.0 CP8
 AREA= 53 ERR= 25.4Z

PB-214 AT 295.2 KEV = 0.15342E-27 UCI

ROIS 6 FROM 333.4 KEV TO 342.4 KEV
PEAK AT 338.3 KEV FWMM= 2.0 KEV
INTEGRAL= 75 RATE= 0.0 CPS
AREA= 31 ERR= 39.32

CS-134 AT 340.4 KEV - 0.87008E-04 UCI

ROIS 7 FROM 348.9 KEV TO 336.0 KEV
PEAK AT 352.0 KEV FUND= 1.4 KEV
INTEGRAL= 79 RATE= 0.0 CPS
AREA= 57 ERR= 24.5%

PB-214 AT 351.9 KEV = 0.10597E-27 UCI

RDIS 0 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.7 KEV FUHM- 2.0 KEV
INTEGRAL- 45 RATE- 0.0 CPS

PR-214 AT 295.2 KEV = 0.15342E-27 UCI

ROIN 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.3 KEV FUMM= 2.0 KEV
INTEGRAL= 75 RATE= 0.0 CP8
AREA= 33 ERR= 37.3%

CS-136 AT 340.6 KEV - 6.87008E-04 WCI

ROIS 7 FROM 348.9 KEV TO 354.0 KEV
PEAK AT 352.0 KEV FWMM= 1.4 KEV
INTEGRAL= 99 RATE= 4.0 CPS
AREA= 57 ERR= 24.5%

PB-214 AT 351.9 KEV - 4.10597E-27 UCI

ROIS S FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.7 KEV FUND 2.0 KEV
INTEGRAL= 45 RATE= 4.0 CPS
AREA= 39 ERR= 28.21

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

RDIB 9 FROM 577.8 KEV TO 584.9 KEV
PEAK AT 583.3 KEV FUNN= 1.4 KEV
INTEGRAL= 43 RATE= 0.0 CP8
AREA= 43 ERR= 12.42

KR-89 AT 585.8 KEV - 0.14476E18 UCI

ROIS 10 FROM 605.9 KEV TO 614.0 KEV
PEAK AT 609.1 KEV FUNM= 2.4 KEV
INTEGRAL= 84 RATE= 0.0 CPS
AREA= 68 ERR= 16.1%

XE-135 AT 608.2 KEV = 0.95728E04 UCI BI-214 AT 609.3 KEV = 0.23735E18 UCI

ROIS 11 FROM 659.5 NEW TO 647.7 KEV
PEAK AT 661.2 KEV FUMM= 3.1 KEV
INTEGRAL= 26 RATE= 0.0 CPS
AREA= 10 ERR= 80.0Z

CS-137 AT 661.6 KEV = 0.21018E-04 UCI

ROIS 12 FROM 907.9 KEV TO 915.5 KEV
PEAK AT 911.3 KEV FUNM= 2.7 KEV
INTEGRAL= 49 RATE= 0.0 CPS
AREA= 34 ERR= 26.4%

ROIS 13 FROM 1454.4 KEV TO 1443.4 KEV
PEAK AT 1461.2 KEV FUHM= 3.7 KEV
INTEGRAL= 154 RATE= 6.0 CPS
AREA= 46 ERR= 43.42

K-40 AT 1460.8 KEV . 0.18326E-02 UCI

CHANNEL #		BATA									
122			18	17	16	17	25	37			
128	28	21	30	51	35	17	17	14			
134	18	11	11	14							
155				12	22	8	17	23			
160	25	22	14	12	13	10	13	13			
327								8			
328	8	10	14	15	17	14	8	7			
336	8 7	•	11	4							
424	9	6	6	7	15	50	60	28			
432	12	10	13	13	15						
528	1	4	7	3	•	14	19	13			
534	1	5	7	3 2	2	14 3					
408	3	2	5	1	•	•	12	10			
616	3 1	2 .	5 7	1 3	2	4					
433		3	3	4	4	4	21	26			
440	15	ĭ	3 4	4	•	•	٠.				

UC BAVIS SAMPLES 22. 23. 25. 26. 8 44 - HOLE LOCATION # 10 (TOP. 5. 15. 8 20 FEET) HOLE 818 (TOP) XEX LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCR 1 LIVE TIME = 2000 TRUE TIME = 2003 22 AUG 84 01:32
COLLECTED AT: 00:54:47.5 22 AUG 84

ROIM 1 FRGM 72.0 KEV TO 81.2 KEV
PEAK AT 77.1 KEV FURN= 1.2 KEV
INTEGRAL= 359 RATE= 0.1 CPS
AREA= 161 ERR= 18.4Z

31-207 AT 75.0 KEV = 0.2757E-03 UC1

ROI# 2 FROM 87.9 KEV TO 96.4 KEV
PEAK AT 93.0 KEV FUHH= 1.4 KEV
INTEGRAL= 203 RATE= 0.1 CPS
AREA= 21 ERR= >>>>X

ROIR 3 FROM 183.1 KEV TO 189.6 KEV
PEAK AT 186.0 KEV FURM= 1.4 KEV
INTEGRAL= 118 RATE= 0.0 CP8
AREA= 66 ERR= 22.7%

U-235 AT 185.7 KEV = 0.57264E-04 UCI

ROIR 4 FROM 235.4 KEV TO 242.2 KEV
PEAK AT 238.7 KEV FUNN= 1.0 KEV
INTEGRAL= 238 RATE= 0.1 CP8
AREA= 121 ERR= 18.12

ROIR 5 FROM 272.0 KEV TO 277.1 KEV
PEAK AT 275.3 KEV FUNN= 1.5 KEV
INTEGRAL= 81 RATE= 0.0 CP8
AREA= 37 ERR= 33.3X

PB-214 AT 295.2 KEV - 0.70342E-29 UCI

RUIS 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.4 KEV FWM- 2.2 KEV
INTEGRAL- 74 RATE- 0.0 CPS
AREA- 38 ERR- 37.42

C8-136 AT 340.6 KEY - 0.1021E-03 UCI

ROIS 7 FROM 348.9 KEV TG 354.0 KEV
PEAK AT 352.3 KEV FUMM= 2.1 KEV
INTEGRAL= 113 RATE= 0.0 CPS
AREA= 85 ERR= 15.2%

PB-214 AT 351.7 KEV . 0.10218E-28 UCI

ROIS 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 511.2 KEV FUMM= 3.1 KEV
INTEGRAL= 43 RATE= 0.0 CPS
AREA= 17 ERR= 58.81 HA-22 AT SII.0 KEV = 0.0000 CO-56 AT SII.0 KEV = 0.0000 CO-58 AT SII.0 KEV = 0.0000 UCT UCI SR-85 AT 514.0 KEV = G.27308E-04 UCI ROIS 9 FROM 577.8 KEV TO 584.9 KEV PEAK AT 583.1 KEV FUMM= 0.7 KEV
INTEGRAL= 72 RATE= 0.0 CPS
AREA= 58 ERR= 17.22 KR-87 AT 585.8 KEV - 0.1173E08 UCI RDIR 10 FROM 603.7 KEV TO 614.0 KEV
PEAK AT 609.4 KEV FUNN- 1.4 KEV
INTEGRAL- 30 RATE- 0.0 CPS
AREA- 30 ERR- 14.01 XE-135 AT 608.2 KEV = 0.61645E04 UCI B1-214 AT 609.3 KEV = 0.44027E16 UCI RGIS 11 FROM 459.5 KEV TO 447.7 KEV PEAK AT >>>>> KEV FUNM= 455.1 KEV 24 RATE 0.0 CPS # ERR= >>>>I INTEGRAL= AREA-RGIB 12 FROM 907.9 KEV TO 915.5 KEV
PEAK AT 911.4 KEV FUMM= 1.4 KEV
INTEGRAL= 32 RATE= 0.0 CP8
AREA= 32 ERR= 15.4Z ROIR 13 FROM 1454.4 KEV TO 1463.6 KEV PEAK AT 1441.4 KEV FUMM= 3.8 KEV
INTEGRAL= 137 RATE= 0.0 CP8
AREA= 11 ERR= >>>>

CHANNEL 8		BATA								
122			11	14	11	17	22	27		
128	30	14	22	50	41	22	14	14		
136	13	10	15	10						
155				18	17	13	17	12		
160	28	23	20	•	11	6	15	15		
327								10		
328	4	3	2	15	17	23	11	11		
334	7	5	5	3						
424	•	12	5	8	•					

K-40 AT 1460.8 KEV - 0.43824E-03 UCI

UC BAVIS BAHPLES 27. 28. 29. 30. & 31 - HOLE LOCATION 811 (4 IN. 5. 10. 15. & 20 FEET) LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCO 1 LIVE TIME = 2004 22 AUG 04 00:32
COLLECTED AT: 22:30:45.3 21 AUG 04

ROIS 1 FROM 72.0 KEV TO \$1.2 KEV
PEAK AT 77.1 KEV FUNN- 1.1 KEV
INTEGRAL- 470 RATE- 0.2 CPS
AREA- 164 ERR- 22.51

D1-207 AT 75.0 KEV - 0.3012E-03 UC1

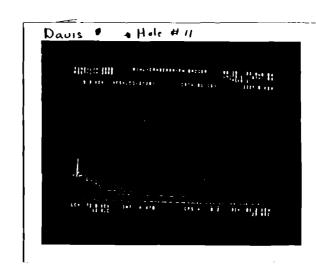
RDIN 2 FROM 09.9 KEV TO 94.4 KEV
PEAK AT 91.1 KEV FUHN- 0.9 KEV
INTEGRAL- 250 RATE- 0.1 CPN
AREA- 35 ERR- 45.41

RBIB 3 FROM 103.1 KEV TO 107.6 KEV
PEAK AT 184.4 KEV FUMM- 1.1 KEV
INTEGRAL- 140 RATE- 0.0 CPB
AREA- 54 ERR- 33.71

9-235 AT 185.7 KEV = 0.48588E-04 UC1

ROIS 4 FROM 235.6 KEV TO 242.2 KEV
PEAK AT 238.8 KEV FUNN= 1.5 KEV
INTEGRAL= 305 RATE= 0.1 CPS
AREA= 180 ERR= 12.21

ROIS 5 FROM 292.0 KEV TO 299.1 KEV
PEAK AT 295.6 KEV FUHN- 1.2 KEV
INTEGRAL- 120 RATE- 0.0 CPS
AREA- 78 ERR- 17.91



9

PB-214 AT 295.2 KEV = 0.33962E-30 UCI

4

ROIB 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.4 KEV FBHM= 1.1 KEV
INTEGRAL= 95 RATE= 0.0 CPB
AREA= 39 ERR= 38.41

CS-136 AT 340.6 KEV = 0.10423E-03 UCI

ROID 7 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 352.2 KEV FUMM= 2.0 KEV
INTEGRAL= 136 RATE= 0.0 CPB
AREA= 94 ERR= 15.91

PB-214 AT 351.9 KEV - 0.27279E-30 UCI

ROIO 0 FROM 507.7 KEV TO 514.2 KEV
PEAK AT \$11.2 KEV FORM- 1.2 KEV
INTEGRAL- 49 RATE- 0.0 CPS
AREA- 43 ERR- 25.51

NA-22 AT 511.0 KEV = 0.0E00 UC1 CO-54 AT 511.0 KEV = 0.0E00 UC1 CO-58 AT 511.0 KEV = 0.0E00 UC1 SR-85 AT 514.0 KEV = 0.74051E-04 UC1

ROID 7 FROM 577.8 KEV TO 584.9 KEV
PEAK AT 583.3 KEV FURM- 1.1 KEV
INTEGRAL- 76 RATE- 0.0 CP8
AREA- 48 ERR- 22.92

KR-87 AT 505.0 KEV = 0.20415E-04 UCI

RGIS 10 FROM 405.9 KEV TO 414.0 KEV
PEAN AT 409.4 KEV FUNN= 2.7 KEV
3KTEGRAL= 91 RATE= 0.0 CPS
AMEA= 75 ERR= 14.42

XE-135 AT 608.2 KEV = 0.7499E04 UCI BI-214 AT 609.3 KEV = 0.43833E14 UCI

ROID 11 FROM 457.5 KEV TO 467.7 KEV
PEAK AT 461.8 KEV FUMM= 1.5 KEV
INTEGRAL= 27 RATE= 0.0 CPB
AREA= 11 ERR= 72.7%

C8-137 AT 661.6 KEV = 0.23119E-04 WCI

ROID 12 FRON 907.0 KEV TO 915.5 KEV
PEAK AT 911.7 KEV FUHN= 3.3 KEV
INTEGRAL= 33 RATE= 0.0 CPS
AREA= 33 ERR= 15.12

ROIS 13 FROM 1454.4 KEV TO 1443.6 KEV
PEAK AT 1441.3 KEV FUMM= 3.2 KEV
INTEGRAL= 169 RATE= 0.0 CPS
AREA= 25 ERR= 96.0Z

K-40 AT 1440.8 KEV = 0.994E-03 UCI

CHANNEL (ı	DATA									
122			12	13	17	19	30	40			
128	35	34	25	53	49	23	20	14			
134	21	14	20	27							
155				17	22	14	11	25			
140	27	39	21	17	17	13	14	13			
327								10			
328	9	8	8	18	17	26	22	Å			
334	12	8	7	9				-			
424	7	4	4	9	24	55	76	57			
432	13	11	12	15	16						
528	3	3	4	7	7	5	24	27			
534	12	7	•	2	6	5 2	_				
608	5	2	4	2	7	13	20	11			

UC DAVIS SAMPLES 32. 33. 34. 35 836 HOLE LOCATION #12 (4 IN . 5 10.15.820 FEET) IE LEHR

TAG NO. = 123 RIML-CANBERRA-FH BABGER PAGE 1
ABCR 1 LIVE TIME = 2000 TRUE TIME = 2003 21 AUG 84 19:39
COLLECTES AT: 03:42:01.4 21 AUG 84

ENERGY(KEV)= 0.20974E-06 *CH*2 + 0.54172E00 *CH +0.5720BE01
PEAK STATISTICS= 1.00 MIN UIDTH= 6 MAX UIDTH= 8

AREA BACKGROUND= 3 XERROR= 1.00
ISO ID UINBOW= 3.0 KEV ISO ID LIBRARY= 1

AGE (BAYS)= 0.70828E01 TABLE 1

ROIB 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 77.0 KEV FUMM= 1.2 KEV
INTEGRAL= 362 RATE= 0.1 CP8
AREA= 110 ERR= 30.0Z

BI-207 AT 75.0 KEY - 0.20202E-03 UCI

ROIR 2 FROM 97.7 KEV TO 96.4 KEV
PEAK AT 93.0 KEV FUHH= 1.4 KEV
INTEGRAL= 210 RATE= 0.1 CP8
AREA= 41 ERR= 58.5%

ROIS 3 FROM 183.1 KEV TO 189.6 KEV
PEAK AT 185.8 KEV FUNN= 0.8 KEV
INTEGRAL= 153 RATE= 0.0 CP8
AREA= 62 ERR= 29.02

U-235 AT 185.7 KEV = 0.53794E-04 UCI

ROIS 4 FROM 233.6 KEV TO 242.2 KEV
PEAK AT 238.6 KEV FUHM= 1.6 KEV
INTEGRAL= 290 RATE= 0.1 CPS
AREA= 160 ERR= 14.32

ROIS 5 FROM 272.0 KEV TO 277.1 KEV
PEAK AT 275.4 KEV FUNM= 2.1 KEV
INTEGRAL= 74 RATE= 0.0 CPS
AREA= 52 ERR= 25.0X

PB-214 AT 275.2 KEV - 0.55294E34 UCI

ROIS 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.5 KEV FORM= 1.7 KEV
INTEGRAL= 69 RATE= 0.0 CPS
AREA= 27 ERR= 44.42

C8-136 AT 340.6 KEY = 0.47228E-04 UCI

ROIS 7 FRON 348.7 KEV TO 354.0 KEV
PEAK AT 352.0 KEV FUNM= 1.7 KEV
INTEGRAL= 108 RATE= 0.0 CPS
AREA= 66 ERR= 21.2%

PB-214 AT 351.7 KEV = 0.46778E34 UCI

RGIE 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.8 KEV FUMM= 1.1 KEV
INTEGRAL= 69 RATE= 0.0 CP8
AREA= 43 ERR= 25.5%

HA-22 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROIS 9 FROM 579.8 KEV TO 384.7 KEV
PEAK AT 583.3 KEV FUMM- 1.8 KEV
INTEGRAL- 46 RATE- 0.0 CPS
AREA- 52 ERR= 17.3X

KR-89 AT 585.8 KEV = 0.17573E-36 UCI

RGIN 10 FROM 605.7 KEV TO 614.0 KEV
PEAK AT 609.4 KEV FUMM= 1.5 KEV
INTEGRAL= 27 RATE= 0.0 CPS
AREA= 77 ERR= 10.3Z

XE-135 AT 608.2 KEV = 0.18806E04 UCI BI-214 AT 607.3 KEV = 0.38178E-03 UCI

RDIR 11 FRBM 459.5 KEU TO 467.7 KEU
PEAK AT 465.2 KEU FUHM- 0.8 KEU
INTEGRAL- 19 RATE- 0.0 CP8
AREA- 19 ERR- 21.02

SB-126 AT 444.2 KEV = 0.50586E-04 UCI 1-132 AT 447.7 KEV = 0.60359E18 UCI

RGIN 12 FROM 907.9 KEV TO 913.5 KEV
PEAK AT 911.5 KEV FUHM= 2.2 KEV
INTEGRAL= 41 RATE= 0.0 CPN
AREA= 41 ERR= 14.6X

ROIS 13 FROM 1454.4 KEV TO 1463.6 KEV
PEAK AT 1461.9 KEV FUNDS 2.0 KEV
INTEGRAL= 150 RATE= 0.0 CPS
AREA= 78 ERR= 24.32

K-40 AT 1460.8 KEV - 0.31975E-02 BCI

CHANNEL .	DATA										
122 128	31	22	1 2 25	15 42	15 32	17 12	27 18	30 8			
134	9 ,	24	•	14							
155				22	17	10	11	19			
160	26	21	21	14	15	13	7	14			
327								5			
328	10	9	6	15	37	15	11	15			
334	10	6	10	4							
424	5	10	•	10	34	64	43	35			
432	7	12	11	22	8						
528	3	4	4	9	4	13	15	12			
534	10	4	7	4	4	1					
608	2	7	2	0	4	13	12	10			
616	3	4	2	3	4	3					
633		2	4	7	5	12	25	16			
640	14	5	4	6	3	2	3				
926						_	3 3	1			
728	5 3	4	7	8	13	8	3	7			
734	3	1	4								
1057				1	2 3	1	2	5 1.			
1064	11	11	18	7	3	v	٧	٠.			
1072	4							_			
1107	_			1	2 3	2 2	1	9 2			
1112	7	19	1 8 1	•	2	4	٧	4			
1120	0	1	'								
1206					_		0	0			
1208	1	2 2	2	0	3	1	2	v			
1216	4	2	1	1	v	v					
1664	1	2 2	0	3	3	7	5	9			
1672	•	2	0	1	•	0	•				
2671						_	_	.1			
2472	•	•	0	1	4	2	5 17	14			
2480	11	17	14	•	24	20	17	•			
2488	1										

AI-DOE-13504 235

UC DAVIS SAMPLE # 37. 38. 39 40 841 HOLE LOCATION #13 (1.5.15 820 FEET) LEHR

TAG NO. = 123 RIHL-CAMBERRA-FH BADGER PAGE 1
ADCH 1 LIVE TIME = 2000 TRUE TIME = 2003 21 AUG 84 02:36
CDLLECTED AT: 01:52:19.9 21 AUG 84

ENERGY(KEV)= 0.20974E-06 9CH^2 + 0.54172E00 9CH +0.5920BE01
PEAK STATISTICS= 1.00 MIN UIDTH= 6 MAX UIBTH= 8
AREA BACKGROUNB= 3 IERROR= 1.00
ISO ID UINDQU= 3.0 KEV ISO ID LIBRARY= 1
AGE (DAYS)= 0.70046E01 TABLE 1

ROIS 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 77.1 KEV FUHM= 0.7 KEV
INTEGRAL= 334 RATE= 0.1 CPS
AREA= 82 ERR= 40.23

BI-207 AT 75.0 KEV = 0.1506E-03 UCI

ROIS 2 FROM 89.9 KEU TO 96.4 KEU
PEAK AT 92.8 KEU FUNM= 2.2 KEU
INTEGRAL= 187 RATE= 0.0 CP8
AREA= 44 ERR= 59.0Z

ROIS 3 FROM 183.1 KEV TO 187.6 KEV
PEAK AT 186.2 KEV FUMM= 1.6 KEV
INTEGRAL= 159 RATE= 0.0 CPS
AREA= 48 ERR= 26.4Z

U-235 AT 185.7 KEV = 0.58979E-04 UCI

ROIN 4 FROM 235.6 KEV TO 242.2 KEV
PEAK AT 238.6 KEV FUHM= 1.4 KEV
INTEGRAL= 252 RATE= 0.1 CPS
AREA= 135 ERR= 16.2X

ROIS 5 FROM 292.0 NEV TO 297.1 NEV
PEAK AT 295.5 NEV FUNM= 0.7 NEV
INTEGRAL= 97 RATE= 0.0 CPS
AREA= 57 ERR= 24.52

PB-214 AT 295.2 KEV = 0.35543E33 UCI

ROIS 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.3 KEV FUNN= 1.2 KEV
INTEGRAL= 77 RATE= 0.0 CPS
AREA= 49 ERR= 22.4%

CS-134 AT 340.4 KEV = 0.12513E-03 UCI

ROIS 7 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 352.1 KEV FUNN= 1.7 KEV
INTEGRAL= 132 RATE= 0.0 CPS
AREA= 104 ERR= 13.42

PB-214 AT 351.9 KEV = 0.43223E33 UCI

RGIS 8 FROM 507.7 KEV TO 514.2 KEV PEAK AT 510.6 KEV FURN- 3.8 KEV INTEGRAL- 43 RATF- 0.0 CPR ROIS 7 FROM 348.9 KEV TO 354.0 KEV
PEAK AT 352.1 KEV FUMM= 1.7 KEV
1NTEGRAL= 132 RATE= 0.0 CPS
AREA= 104 ERR= 13.4Z

1

PB-214 AT 351.9 KEV = 0.43223E33 UCI

ROIS 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.6 KEV FUMM= 3.8 KEV
INTEGRAL= 43 RATE= 0.0 CPS
AREA= 30 ERR= 26.62

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROIN 9 FROM 579.8 KEV TO 584.9 KEV
PEAK AT 583.2 KEV FUHM= 1.6 KEV
INTEGRAL= 69 RATE= 0.0 CP8
AREA= 55 ERR= 18.12

KR-89 AT 585.8 KEV = 0.82708E30 UCI

ROIS 10 FROM 405.7 KEV TO 414.0 KEV
PEAK AT 408.8 KEV FWMM= 2.1 KEV
INTEGRAL= 47 RATE= 0.0 CPS
AREA= 49 ERR= 11.52

XE-135 AT 608.2 KEV = 0.14658E04 UCI 81-214 AT 609.3 KEV = 0.7507E-05 UCI

ROIB 11 FROM 659.5 KEV TO 667.7 KEV
PEAK AT 661.7 KEV FUMM= 3.0 KEV
INTEGRAL= 28 RATE= 0.0 CPB
AREA= 12 ERR= 66.62

CS-137 AT 461.4 KEV = 0.2522E-04 UCI

ROIB 12 FROM 907.7 KEV TO 915.5 KEV
PEAK AT 911.8 KEV FUNM= 1.5 KEV
INTEGRAL= 39 RATE= 0.0 CPB
AREA= 39 ERR= 15.33

ROIB 13 FROM 1454.4 KEV TO 1443.6 KEV
PEAK AT 1460.8 KEV FUMM= 4.5 KEV
INTEGRAL= 113 RATE= 0.0 CP8
AREA= 41 ERR= 43.9%

K-40 AT 1460.8 KEV = 0.16334E-02 UCI

122			16	11	17	15	29	35
128	26	17	13	44	31	14	7	7
136	11	14	12	7				
155				14	23	7	16	19
140	19	23	17	11	12	7 3	12	11
327								6
328	8	3	13	11	27	28	21	7
336	8 5	10	10	10				
424	3	10	7	4	22	54	58	26
432	13	10	13	4	19			
528	5	2	3	3	7	7	25	15
534	10	2	3	3	7 3	7 5		
408	4	5	1	3	6	14	15	•
414	3	5 4	1 5	3	0	6		
433		2	2	4	10	12	25	30
440	20	2 •	2 4	6 7	2	t	•	
726							•	2
728	4	4	8	5	4	5	9 5	4
136	0	4 2	•					
1059				2	0	2	2	•

HC BAVIS SAMPLES 45. 46. 47. 148 HOLE LOCATIONS WIS (5 FT) WIS (TOP AND 5 FT) AND 20 (TOP) LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ABCR 1 LIVE TIME = 2000 TRUE TIME = 2002 21 AUG 84 01:30
COLLECTED AT: 01:04:30.8 21 AUG 84

ROID 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 77.3 KEV FUNN= 0.7 KEV
INTEGRAL= 257 RATE= 0.1 CP8
AREA= 61 ERR= 47.5%

B1-207 AT 75.0 KEV = 0.11203E-03 UCI

RGIB 2 FROM 89.9 KEV TO 94.4 KEV
PEAK AT >>>>> KEV FURN= 84.0 KEV
INTEGRAL= 159 RATE= 0.0 CP8
AREA= 16 ERR= >>>>X

ROID 3 FROM 183.1 KEV TO 187.6 KEV
PEAK AT 185.7 KEV FUHM= 0.8 KEV
INTEGRAL= 102 RATE= 0.0 CP8
AREA= 37 ERR= 40.5%

U-235 AT 185.7 KEV = 0.32103E-04 UCI

ROIB 4 FROM 235.4 KEV TO 242.2 KEV
PEAK AT 238.8 KEV FUHM= 1.0 KEV
INTEGRAL= 177 RATE= 0.0 CPS
AREA= 73 ERR= 27.3E

ROID 5 FROM 292.0 KEV TO 299.1 KEV
PEAK AT 295.3 KEV FUMM= 1.4 KEV
INTEGRAL= 80 RATE= 0.0 CP8
AREA= 38 ERR= 34.21

PB-214 AT 295.2 KEV = 0.72432E32 UCI

ROIG 6 FROM 333.4 KEV TO 342.4 KEV
PEAK AT 338.7 KEV FUMM= 1.1 KEV
INTEGRAL= 60 RATE= 0.0 CPS
AREA= 32 ERR= 34.3X

C8-134 AT 340.4 KEV = 0.81581E-04 UCI

ROIS 7 FROM 348.9 KEV TO 336.0 KEV
PEAK AT 352.0 KEV FUHM= 1.3 KEV
INTEGRAL= 93 RATE= 0.0 CPS
AREA= 51 ERR= 25.41

PB-214 AT 351.9 KEV = 0.64792E32 UCI

ROID 8 FROM 507.7 KEV TO 514.2 KEV PEAK AT 511.2 KEV FUNN= 2.4 KEV ROIS 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 511.2 KEV FUMM= 2.4 KEV
IMTEGRAL= 50 RATE= 0.0 CPS
AREA= 37 ERR= 21.42

MA-22 AT 511.0 KEV = 0.0E00 UCI C0-34 AT 511.0 KEV = 0.0E00 UCI C0-38 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.43113E-04 UCI

ROIS 9 FROM 577.8 KEV TO 586.7 KEV
PEAK AT 583.2 KEV FWMM= 1.6 KEV
INTEGRAL= 52 RATE= 0.0 CP8
AREA= 52 ERR= 13.42

KR-89 AT 585.8 KEV = 0.34849E26 UCI

ROIN 10 FROM 605.9 KEV TO 614.0 KEV
PEAK AT 609.0 KEV FUHH= 1.0 KEV
INTEGRAL= 62 RATE= 0.0 CP8
AREA= 46 ERR= 21.72

XE-135 AT 408.2 KEV = 0.92183E03 UCI 81-214 AT 409.3 KEV = 0.10143E-05 UCI

ROIB 11 FROM 659.5 KEV TO 647.7 KEV
PEAK AT 641.7 KEV FUMM= 2.0 KEV
INTEGRAL= 17 RATE= 0.0 CPB
AREA= 17 ERR= 23.5%

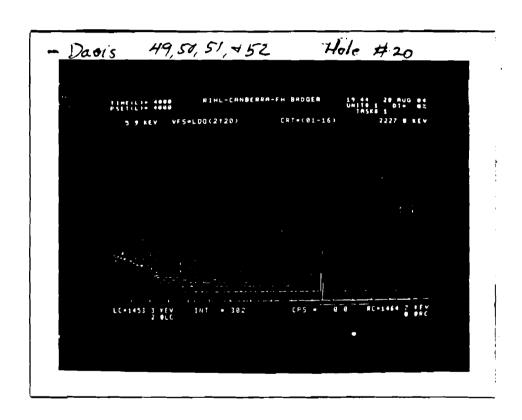
C9-137 AT 661.6 KEV = 0.35728E-04 UCI

ROIS 12 FROM 907.9 KEV TO 915.5 KEV
PEAK AT 911.7 KEV FUNM= 2.1 KEV
INTEGRAL= 29 RATE= 0.0 CPS
AREA= 14 ERR= 57.1%

ROIS 13 FROM 1454.4 KEV TO 1443.6 KEV
PEAK AT 1442.8 KEV FUNN= 1.8 KEV
INTEGRAL= 107 RATE= 0.0 CPS
AREA= 17 ERR= >>>>X

K-40 AT 1460.8 KEV = 0.67728E-03 UCI

CHANNEL #		DATA								
122			17	13	13	8	15	27		
126	21	12	8	23	31	16	8	8		
136	14	9	8	8						
155				17	11	11	13	17		
160	10	15	14	14	10	8	7	12		
327								8		
328	3	5	9	11	17	9	12	5		
334	6	•	0	9						
424	2	5	9	6	9	27	48	24		
432	6	8	8	12	13					
528	3	2	4	7	4	10	14	17		
534	4	3	3	2	7	0				
608	3	0	4	3	3	5	10			
616	2	ž	7	ī	4	3	••	•		
633		4	4	1	7	7	18	21		
640	11	4	2	1	3	2	4			
926							0	4		
928	1	6	3	7		•	4	3		
736	1	2	1					•		
1059	_			0	1	0	0	2 2		
1064 1072	7 2	14	12	6	0	3	1	2		
	-			_	_	_	_	_		
1107			_	2 7	2	2	3	2		
1112	10	17	7	7	7	0	1	0		
1120	•	0	0							
1206			_	_	_		0 .	0		
1208	1	1	3	3	0	1	2	2		
1216	1	0	0	1	1	1.				
1664	1	2	0	2	2	2	6	4		
1672	4	3	0		1	1	1			
2671								1		
2472	0	0	0	0	0	1	2	6		
2480	5	•	12	9	12	17	20	7		
2488	6									



UC BAVIS SMAPLES 49. 30. 31. 52 - HOLE LOCATION #20 5.10.15. 8 20 FEET LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ADCH 1 LIVE TIME = 4000 TRUE TIME = 4000 20 AUG 84 19:37
COLLECTED AT: 04:17:23.2 20 AUB 84

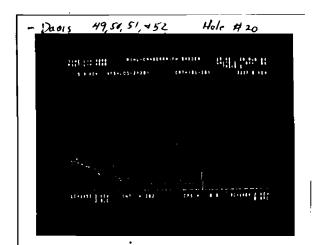
ROIS 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 74.8 KEV FORM= 1.5 KEV
INTEGRAL= 730 RATE= 0.1 CPS
AREA= 224 ERR= 20.7I

DI-207 AT 75.0 KEV . 0.20752E-03 UCI

- ROIS 2 FROM 87.7 KEV TO 94.4 KEV
 PEAK AT 93.1 KEV FUHN= 1.0 KEV
 INTEGRAL= 431 RATE= 0.1 CPS
 AREA= 80 ERR= 42.52
- ROIS 3 FROM 183.1 KEV TO 189.6 KEV
 PEAK AT 185.8 KEV FUMM= 1.4 KEV
 INTEGRAL= 299 RATE= 0.0 CPS
 AREA= 65 ERR= 43.0X

U-235 AT 185.7 KEV = 0.28198E-04 UCI

- ROIM 4 FROM 235.6 KEV TO 242.2 KEV
 PEAK AT 238.6 KEV FUHM= 1.5 KEV
 THTEGRAL= 507 RATE= 0.1 CPS
 AREA= 286 ERR= 10.03
- RGIO 5 FRGM 292.0 KEV TO 299.1 KEV
 PEAK AT 295.0 KEV FUMM= 1.2 KEV
 INTEGRAL= 180 RATE= 0.0 CP8
 AREA= 82 ERR= 24.31



PR-214 AT 295.2 KEV = 0.73251E18 UCI

ROIS 6 FRON 335.4 KEV TO 342.4 KEV
PEAK AT 338.3 KEV FUHM= 1.9 KEV
INTEGRAL= 148 RATE= 0.0 CPS
AREA= 78 ERR= 21.72

C9-134 AT 340.6 KEV = 0.94967E-04 UCI

ROIS 7 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 351.6 KEV FUHM= 1.5 KEV
INTEGRAL= 186 RATE= 0.0 CPS
AREA= 116 ERR= 15.52

PB-214 AT 351.9 KEV = 0.69065E18 UCI

ROIS 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.4 KEV FUNN= 2.6 KEV
INTEGRAL= 114 RATE= 0.0 CPS
AREA= 62 ERR= 24.1Z

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROIS 9 FRON 579.8 KEV TO 584.9 KEV
PEAK AT 583.2 KEV FUNN~ 1.0 KEV
INTEGRAL= 116 RATE= 0.0 CPS
AREA= 102 ERR= 11.7%

KR-89 AT 585.8 KEV = 0.99439E-16 UCI

ROIS 10 FROM 605.7 KEV TO 614.0 KEV
PEAK AT 609.1 KEV FUNN= 2.1 KEV
INTEGRAL= 130 RATE= 0.0 CPS
AREA= 114 ERR= 11.42

XE-135 AT 608.2 KEV = 0.23318E03 UCI BI-214 AT 607.3 KEV = 0.16106E-24 UCI

ROIS 11 FROM 639.5 KEV TO 667.7 KEV
PEAK AT 660.6 KEV FURN- 1.1 KEV
INTEGRAL- 43 RATE- 0.0 CPS
AREA- 11 ERR- >>>>Z

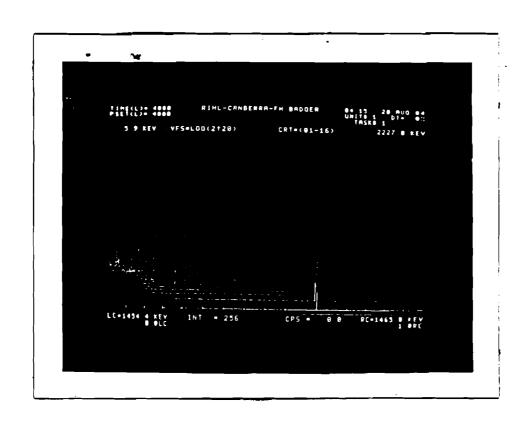
RB-89 AT 457.7 KEV = 0.10085E17 UCI AG-110N AT 457.7 KEV = 0.10474E-04 UCI CS-137 AT 441.6 KEV = 0.11558E-04 UCI

ROIS 12 FROM 907.9 KEV TO 915.5 KEV
PEAK AT 911.0 KEV FWHM= 4.1 KEV
INTEGRAL= 71 RATE= 0.0 CPS
AREA= 41 ERR= 29.2%

ROIS 13 FROM 1454.4 NEV TO 1443.6 NEV
PEAK AT 1460.8 NEV FUNN= 4.0 NEV
INTEGRAL= 278 RATE= 0.0 CPS
AREA= 172 ERR= 15.12

K-49 AT 1440.8 KEV = 0.34242E-02 UCI

CHANNEL &				3	ATA			
122			28	28	27	41	47	56
128	49	41	62	82	68	36	21	27
136	25	28	37	27				
155				42	37	17	27	45 18
160	45	59	39	29	25	23	25	16
327								25
320	19	16	21	32	41	37	25	15
334	16	15	19	18				
	_	_					108	59
424	15	5	17	20	62	111	198	34
432	14	27	18	25	24			
528	7	9	8	9	14	33	39	18
534	12	5	6	2	7	11		
	_	_			17	26	23	17
408	5	7	6 7	9	4	4	23	17
414	7	•	,	•	•	•		
433		4	2	7	12	25	41	38
440	11	13	•	4	5	4	•	
926							3	4
92 6	•	10	15	18	16	12	Ť	6
736	ž		2		••			
	_					_	_	
1 05 7				. 1	1	. 3	5 2	12
1064	16	35	17	10	2	4	2	3
1072	3							
1107				1	0	2	6	11
1112	30	26	21	12	4	4	1	4
1120	4	0	2					
1206							1	3
1208	5	3	1	2	2	4	2	1
1216	3		À	ī	2	3	-	
	. •	•						
1664	2	0	7	5 .	5	11	•	9
1672	10	6	1	2	2	1	2	
2671								2
2672	٥	0	1	0	4	13	13	18
2680	34	29	29	40	39	32	26	12
2688	4		•	••	•		-	
	•							



UC DAVIS SAMPLE 53. 54. 55. 456 HOLE LOCATION 21 (5 IN AND 5 FT) HOLE 22(3 IN AND 5 FT) LEHR

ROID 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 76.7 KEV FWHM= 1.2 KEV
INTEGRAL= 599 RATE= 0.1 CP8
AREA= 185 ERR= 22.71

BI-207 AT 75.0 KEV = 0.14987E-03 UCI

ROIS 2 FROM ST.T KEV TO 76.4 KEV
PEAK AT 72.7 KEV FUHN= 1.0 KEV
INTEGRAL= 337 RATE= 0.0 CPS
AREA= 14 ERR= >>>3

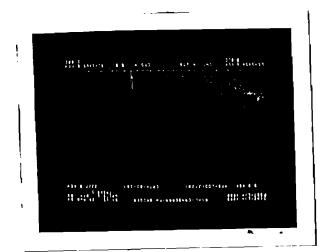
ROID 3 FROM 183.1 KEV TO 187.4 KEV
PEAK AT 184.0 KEV FWHH- 0.7 KEV
INTEGRAL- 212 RATE- 0.0 CP8
AREA- 36 ERR- 41.01

U-235 AT 185.7 KEV . 0.24294E-04 UCI

ROID 4 FROM 235.6 KEV TO 242.2 KEV
PEAK AT 236.6 KEV FURM= 1.4 KEV
INTEGRAL= 390 RATE= 0.0 CP8
AREA= 156 ERR= 18.52

ROIN 5 FROM 272.0 MEV TO 277.1 MEV
PEAK AT 275.0 MEV FUMM- 1.4 MEV
INTEGRAL- 153 RATE- 0.0 CPS
AREA- 03 ERR- 20.4%

PB-214 AT 295.2 KEV = 0.43217E18 UCI



ROIS 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.0 KEV FUMM= 0.7 KEV
INTEGRAL= 115 RATE= 0.0 CPS
AREA= 45 ERR= 35.5%

CS-136 AT 340.6 KEV . 0.54747E-04 UCI

ROID 7 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 351.7 KEV FUNN= 1.8 KEV
INTEGRAL= 179 RATE= 0.0 CPS
AREA= 109 ERR= 16.52

PB-214 AT 351.9 KEV = 0.37828E18 UCI

ROIR 8 FROM 507.7 KEV TO 514.2 KEV PEAK AT 510.7 KEV FUNM= 2.2 KEV

ROIN 4 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.0 KEV FUND 0.7 KEV
INTEGRAL= 115 RATE= 0.0 CPS
AREA= 45 ERR= 35.52

CS-136 AT 340.6 KEV . 0.34747E-04 UCI

ROIR 7 FROM 348.9 KEV TO 334.0 KEV
PEAK AT 351.7 KEV FUNN= 1.8 KEV
INTEGRAL= 179 RATE= 0.0 CP8
AREA= 109 ERR= 16.52

PB-214 AT 351.9 KEV = 0.37828E18 UC1

ROIN 8 FROM 507.7 KEV TO 514.2 KEV
PEAK AT 510.7 KEV FUMM= 2.2 KEV
INTEGRAL= 100 RATE= 0.0 CPS
AREA= 48 ERR= 27.1%

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI

ROIS 9 FROM 579.8 KEV TO 384.9 KEV PEAK AT 583.0 KEV FMM= 1.4 KEV INTERRAL= 95 RATE= 0.0 CPS AREA= 47 ERR= 17.9%

KR-09 AT 585.6 KEV = 0.481E-16 UCI

ROIS 10 FROM 405.7 KEV TO 414.6 KEV
PEAK AT 407.2 KEV FUMM= 2.2 KEV
INTEGRAL= 117 RATE= 0.0 CPS
AREA= 101 ERR= 11.82

XE-135 AT 408.2 KEV = 0.20117E03 UCI BI-214 AT 409.3 KEV = 0.40974E-25 UCI

ROIS 11 FROM 459.3 KEV TO 447.7 KEV
PEAK AT 441.1 KEV FURM 0.8 KEV
INTEGRAL= 43 RATE= 0.0 CPS
AREA= 15 ERR= 64.6Z

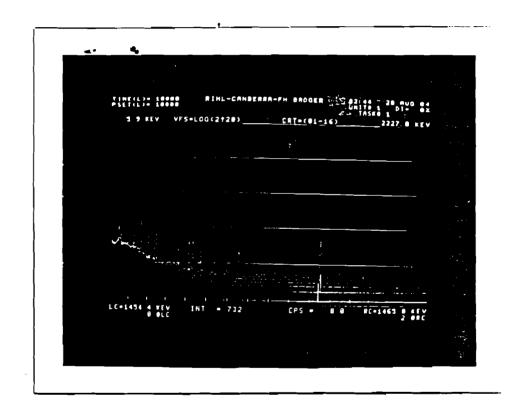
CS-137 AT 641.4 KEV = 0.15761E-04 UCI

ROIS 12 FROM 907.9 KEY TO 915.5 KEY
PEAK AT 911.1 KEY FUMM= 2.7 KEY
INTEGRAL= 45 RATE= 0.0 CPS
AREA= 35 ERR= 31.41

ROIN 13 FROM 1454.4 KEV TO 1443.6 KEV
PEAK AT 1440.9 KEV FUHM= 3.6 KEV
INTEGRAL= 254 RATE= 0.0 CP8
AREA= 146 ERR= 16.42

K-40 AT 1460.8 KEV = 0.27083E-02 UCI

CHANNEL 8				1	ATA			
122			18	29	26	30	48	51
128	40	25	53	44	43	33	23	25
134	17	18	20	32				
155				38	32	28	19	28
160	35	32	29	22	20	21	13	22
327								12
328	21	11	20	17	30	25	15	11
334	11	7	7	15				
424	14	14	13	11	44	77	81	37
432	10	15	13	22	33			
528	4	4	3	7	16	24	33	17
534	7	8	4	2	7	11		
408	8	7	4	4	12	24		7
414	11	ě	4	3	8	5	•	•
433		•	. 4	8	13	27	37	42
440	17	5	3	2	7	2	4	
924							3	4
728	7	7	10	14	12	14	•	7
734	4	4	2					
1057				4	2	3	4	
1064	15	21	14	7	5	3	2	2
1072	, 1							
1107				0	2	2 3	4	11
1112	16	24	21	16	4	3	2	2
1120	2	2	4					
1206							3	3
1208	7	13	5	5	4	1	3	5
1214	3	2	3	1	3	2		
1664	2	2	4	4	8	9	8	•
1472	8	3	1	1	1	3	2	
2471								0
2472	1	1	2	1	5	4	10	15
2480	17	25	25	34	37	34	26	8
2488	3							



UC BAVIS SAMPLES 57. 58. 59. 40. 61 -- HOLE BAMPLELOCATION 23 44 & 5 FT. AND 10 FT 1 HOLE 24 3 " & 5 FT LEHR

TAG NG. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ABCH 1 LIVE TIME = 10000 TRUE TIME = 10014 20 AUG 84 02:42
COLLECTED AT: 00:17:49.7 20 AUG 84

ROIO 1 FROM 72.0 KEV TO 81.2 KEV
PEAK AT 77.1 KEV FUNM= 1.3 KEV
INTEGRAL= 2015 RATE= 0.2 CP8
AREA= 503 ERR= 15.92

DI-207 AT 75.0 KEV = 0.10475E-03 UCI

RBIB 2 FROM 89.9 NEV TO 96.4 NEV
PEAK AT 92.7 NEV FUMM= 1.5 NEV
INTEGRAL= 1102 RATE= 0.1 CPB
AREA= 166 ERR= 33.1%

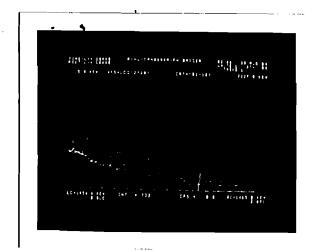
ROID 3 FROM 103.1 KEV TO 189.4 KEV
PEAK AT 184.0 KEV FUHH= 1.3 KEV
INTEGRAL= 774 RATE= 0.0 CPB
AREA= 170 ERR= 25.22

W-235 AT 185.7 KEV - 0.3088E-04 WCI

ROIB 4 FROM 235.6 KEV TO 242.2 KEV
PEAK AT 230.7 KEV FUNM= 1.2 KEV
INTEGRAL= 1469 RATE= 0.1 CPB
AREA= 715 ERR= 7.6X

ROID 5 FROM 292.0 KEV TO 299.1 KEV
PEAK AT 295.3 KEV FUHM* 1.4 KEV
INTEGRAL* 513 RATE* 0.0 CP8
AREA* 247 ERR* 13.32

PB-214 AT 295.2 KEV = 0.10014E16 UCI



RGIE 6 FROM 335.4 KEV TO 342.4 KEV
PEAK AT 338.6 KEV FUHM= 1.0 KEV
INTEGRAL= 400 RATE= 0.0 CPS
AREA= 134 ERR= 23.12

CS-136 AT 340.6 KEV - 0.44688E-04 UCI

ROIM 7 FROM 348.9 KEV TO 354.0 KEV
PEAK AT 352.0 KEV FUMM= 1.7 KEV
INTEGRAL= 578 RATE= 0.0 CPS
AREA= 348 ERR= 8.42

PB-214 AT 351.9 KEV = 0.17880E16 UCI

ROIR 8 FROM 507.7 KEV TO \$14.2 KEV
PEAK AT 510.9 KEV FUNN- 1.8 KEV
INTEGRAL- 247 RATE- 0.0 CPS
AREA- 111 ERR- 21.42

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROIB 9 FROM 579.8 NEV TO 504.7 KEV
PEAK AT 503.1 KEV FUNM= 2.0 KEV
INTEGRAL= 337 RATE= 0.0 CPS
AREA= 239 ERR= 7.4%

KR-89 AT 585.8 KEV = 0.14814E-38 UCI

ROIS 10 FROM 605.7 KEV TO 614.0 KEV
PEAK AT 607.4 KEV FUHM= 2.1 KEV
1MTEGRAL= 406 RATE= 0.0 CPS
AREA= 262 ERR= 10.62

XE-135 AT 400.2 KEV = 0.15805E03 UCI 81-214 AT 409.3 KEV = 0.35278E-28 UCI

ROIS 11 FROM 659.5 KEV TO 647.7 KEV
PEAK AT 662.1 KEV FUMM= 1.7 KEV
INTEGRAL= 199 RATE= 0.0 CPS
AREA= 55 ERR= 43.62

CS-137 AT 661.6 KEV = 0.23117E-04 UCI

ROIS 12 FROM 907.9 KEV TO 915.3 KEV
PEAK AT 911.1 KEV FUHM- 2.8 KEV
INTEGRAL- 218 RATE- 0.0 CPS
AREA- 143 ERR- 11.92

ROIS 13 FROM 1454.4 KEV TO 1463.6 KEV
PEAK AT 1461.2 KEV FUND: 4.2 KEV
INTEGRAL= 699 RATE= 0.0 CPS
AREA= 105 ERR= 46.62

K-40 AT 1460.8 KEV = 0.83444E-03 UCI

CHANNEL 0	DATA									
122			76	87	84	84	122	178		
128	159	19	144	230	172	107	47	54		
136	50	78	98	63						
155				119	92	65	43	119		
140	131	122	75	64	74	47	40	51		
327								60		
328	44	47	37	73	114	110	67	44		
334	51	41	47	39						
424	44	45	37	44	120	300	367	164		
432	42	41	74	72	77					
520	23	24	21	16	31	48	104	70		
534	36	20	25	17	11	23				
408	20	14	21	15	37	45	74	47		
414	26	15	19	27	19	19				
633		19	15	10	23	43	119	127		
640	73	29	20	10	21	13	14			
926							•	15		
720	7	13	23	40	42	37	18	21		
736	13	14	15							
1059				5	12	۵	•	30		
1044	50	44	75	33	15	10	10	7		
1072	7									
1107					4	10	14	29		
1112	50	69	76	42	22	17	5	5		
1120	12	11	10							

UC DAVIS SAMPLES 62. 63. 64. 65. 866 HOLE LOCATIONS 24 -35 826 24 TIP -250 IN 85 FT- 26/9 IN 85 FT LEHR

* TAG NO. = 123 RIHL-CAMBERRA-FN BABGER PAGE 1
ABCB 1 LIVE TIME = 2000 TRUE TIME = 2001 19 AUG 84 22:34
COLLECTED AT: 21:59:03.5 19 AUG 84

ROIN 1 FROM 72.0 KEV TO 78.5 KEV
PEAK AT 77.2 KEV FUNN= 1.2 KEV
INTEGRAL= 310 RATE= 0.1 CPS
AREA= 63 ERR= 46.03

BI-207 AT 75.0 KEV = 0.11549E-03 UCI

ROIN 2 FROM 83.4 KEV TO 89.9 KEV
PEAK AT 87.7 KEV FWMM= 0.7 KEV
INTEGRAL= 215 RATE= 0.1 CP8
AREA= 20 ERR= >>>>Z

CB-107 AT 88.0 KEV = 0.30183E-03 UCI BI-207 AT 84.8 KEV = 0.891E-04 UCI NP-237 AT 86.5 KEV = 0.93823E-04 UCI

ROIN 3 FROM 182.5 KEV TO 187.0 KEV
PEAK AT 185.6 KEV FUHM= 0.7 KEV
INTEGRAL= 160 RATE= 0.0 CP8
AREA= 56 ERR= 33.7%

U-235 AT 185.7 KEV = 0.48588E-04 UCI

ROIN 4 FROM 235.1 KEV TO 241.6 KEV
PEAK AT 238.8 KEV FUNN= 1.4 KEV
INTEGRAL= 231 RATE= 0.1 CP8
AREA= 127 ERR= 16.52

ROIN 5 FROM 290.9 KEV TO 297.4 KEV
PEAK AT 295.4 KEV FUNN= 1.5 KEV
INTEGRAL= 78 RATE= 0.0 CPS
AREA= 26 ERR= 50.02

PB-214 AT 295.2 KEV = 0.24203E14 UCI

RDIO 6 FROM 348.7 KEV TO 355.4 KEV
PEAK AT 352.0 KEV FUMM= 1.0 KEV
INTEGRAL= 122 RATE= 0.0 CP8
- AREA= 83 ERR= 16.8Z

PB-214 AT 351.7 KEV = 0.55751E14 UCI

ROIS 7 FROM 507.2 KEV TO 513.7 KEV
PEAK AT 510.2 KEV FUMM= 2.9 KEV
INTEGRAL= 69 RATE= 0.0 CPS
AREA= 43 ERR= 25.5%

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

RGIU 8 FROM 604.4 KEV TO 612.7 KEV
PEAK AT 609.7 KEV FUHM= 1.3 KEV
INTEGRAL= 70 RATE= 0.0 CP8
AREA= 44 ERR= 25.0X

XE-135 AT 608.2 KEV = 0.11124E03 UCI BI-214 AT 607.3 KEV = 0.23587E-30 UCI

ROIM 9 FROM 907.4 KEV TO 913.9 KEV
PEAK AT 911.5 KEV FWMM= 1.8 KEV
INTEGRAL= 45 RATE= 0.0 CPS
AREA= 32 ERR= 25.0Z

ROIS 10 FROM 1454.5 KEV TO 1445.8 KEV
PEAK AT 1441.1 KEV FUMM- 4.5 KEV
INTEGRAL- 174 RATE- 0.0 CPS
AREA- 174 ERR- 7.3%

K-40 AT 1440.8 KEV = 0.70118E-02 UCI

CHANNEL 0	BATA								
122			14	17	19	16	26	28	
120	35	21	19	44	33	25	11		
143								16	
144	11	19	13	13	20	15	16	31	
152	16	16	19	10					
324							8	5	
320	7	9	11	20	29	13	16		
334	7	11	14	_				_	
423								4	
424	4	7		9	14	50	54	32	
432	14								

UC BAVIS SAMPLES 67.68.69.70.271 HOLE SAMPLE 276 IN TO 20 FT LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCR 1 LIVE TIME = 10000 TRUE TIME = 10018 19 AUG 84 19:32
COLLECTER AT: 05:12:45.1 19 AUG 84

ENERGY(KEV)= 0.27048E-07 **CM**2 + 0.54313E00 **CM**+0.61837E01
PEAK STATISTICS= 1.00 **IN UIDTH= 6 **MAX UIDTH= 6
AREA BACKGROUND= 3 **IERROR= 1.00
ISO ID UINDOU= 3.0 KEV ISO ID LIBRARY= 1
AGE (DAYS)= 0.51458E01 **TABLE 1

ROIS 1 FROM 55.6 KEV TO 63.2 KEV
PEAK AT 57.6 KEV FUHM= 2.0 KEV
INTEGRAL= 1009 RATE= 0.1 CPS
AREA= 64 ERR= 90.62

TA-182 AT 38.0 KEV = 0.14143E-03 UCI AM-241 AT 59.5 KEV = 0.33261E-04 UCI

ROIS 2 FROM 73.5 KEV TO 79.5 KEV
PEAK AT 77.5 KEV FUNM= 1.3 KEV
INTEGRAL= 1508 RATE= 0.1 CPS
AREA= 440 ERR= 13.4%

I-131 AT 80.2 KEV = 0.30339E-02 UCI BI-207 AT 75.0 KEV = 0.1616E-03 UCI

ROIS 3 FROM 87.8 KEV TO 76.3 KEV
PEAK AT 93.1 KEV FUNM= 1.6 KEV
INTEGRAL= 1103 RATE= 0.1 CPS
AREA= 180 ERR= 30.5X

ROIN 4 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 239.5 KEV FUMM= 1.3 KEV
INTEGRAL= 1391 RATE= 0.1 CP8
AREA= 716 ERR= 7.6%

PB-214 AT 241.9 KEV - 0.16112E04 UCI

ROID 5 FROM 293.0 KEV TO 297.5 KEV
PEAK AT 294.2 KEV FUHM= 1.5 KEV
INTEGRAL= 458 RATE= 0.0 CP8
AREA= 237 ERR= 12.41

PB-214 AT 293.2 KEV . 0.23888E03 UCI

RDIR 6 FROM 348.7 KEV TO 356.5 KEV
PEAK AT 353.0 KEV FUMM= 1.4 KEV
INTEGRAL= 524 RATE= 0.0 CP8
AREA= 344 ERR= 7.01

PB-214 AT 351.9 KEV = 0.2311E03 UCI

ROIS 7 FROM 508.1 KEV TO 510.9 KEV
PEAK AT 512.1 KEV FUNN= 2.1 KEV
INTEGRAL= 333 RATE= 0.0 CPS
AREA= 123 ERR= 24.02

NA-22 AT 511.0 KEV = 0.0E00 UCI CD-56 AT 511.0 KEV = 0.0E00 UCI CD-58 AT 511.0 KEV = 0.0E00 UCI SR-65 AT 514.0 KEV = 0.41147E-04 UCI RGIN 8 FROM 579.8 KEV TO 589.8 KEV
PEAK AT 584.8 KEV FUMM= 2.3 KEV
INTEGRAL= 371 RATE= 0.0 CP8
AREA= 281 ERR= 8.81

KR-89 AT 585.8 KEV = 0.30522E07 UCI

RGIB 9 FROM 404.4 KEV TO 415.6 KEV
PEAK AT 410.8 KEV FUHM= 1.4 KEV
INTEGRAL= 341 RATE= 0.0 CP8
AREA= 235 ERR= 11.42

XE-135 AT 408.2 KEV - 0.33035E02 UCI 81-214 AT 607.3 KEV - 0.174E32 UCI

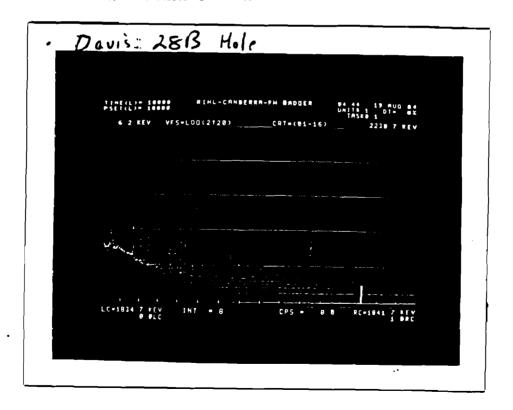
ROIS 10 FROM 458.5 KEV TO 447.8 KEV
PEAK AT 442.4 KEV FURM= 0.7 KEV
INTEGRAL= 157 RATE= 0.0 CPS
AREA= 49 ERR= 42.82

CS-137 AT 661.6 NEV = 0.20594E-04 UCI

ROIS 11 FROM 908.4 KEV TO 914.9 KEV
PEAK AT 913.6 KEV FUNN- 1.1 KEV
INTEGRAL- 194 RATE- 0.0 CPS
AREA- 0 ERR- 0.02

RDIS 12 FROM 1454.0 KEV TO 1444.7 KEV
PEAK AT 1442.3 KEV FUMM= 0.3 KEV
INTEGRAL= 351 RATE= 0.0 CP8
AREA= 0 ERR= 0.0Z

K-40 AT 1460.8 KEV = 0.0E00 UC1



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74 UC BAVIS SAMPLES 24. 25. 26. 28.27 HOLE LOCATION 28D SURFAGE TO 20 FEET IN 5 FT INCRIN. LEHR

TAG NG. = 123 RIHL-CAMBERRA-FH BADGER PAGE 1
ADCN 1 LIVE TIME = 10000 TRUE TIME = 10023 17 AUG 84 04:43
COLLECTED AT: 22:22:45.4 17 AUG 04

EMERGY(KEV)= 0.27048E-07 *CM^2 + 0.54313E00 *CM +0.41837E01
PEAK STATISTICS= 1.00 MIN UIDTH= 4 MAX WIDTH= 8
AREA SACKSROUND= 3 ZERROR= 1.00
180 IB UINDBU= 3.0 KEV ISB ID LIBRARY= 1
ABE (BAYD)= 0.3841E01 TABLE 1

ROID 1 FROM 55.6 KEV TO 43.2 KEV
PEAK AT >>>>> KEV FORM= 657.0 KEV
INTEGRAL= 944 RATE= 0.0 CPB
AREA= 44 ERR= >>>>I

ROIN 2 FROM 73.5 KEV TO 79.5 KEV
PEAK AT 77.6 KEV FUNN* 1.1 KEV
INTEGRAL* 1416 RATE* 0.1 CPN
AREA* 340 ERR* 14.31

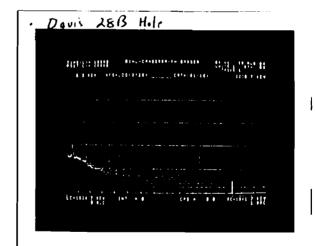
I-131 AT 00.2 KEV = 0.22221E-02 UCI BI-207 AT 75.0 KEV = 0.13221E-03 UCI

ROIR 3 FROM 09.0 NEV TO 94.3 NEV
PEAK AT 93.3 NEV FUMM= 1.4 NEV
INTEGRAL= 1040 RATE= 0.1 CP8
AREA= 156 ERR= 34.62

ROID 4 FROM 234.0 KEV TO 242.4 KEV
PEÁK AT 239.5 KEV FONM- 1.4 KEV
INTEGRAL- 1200 RATE- 0.1 CPB
AREA- 620 ERR- 0.71

PB-214 AT 241.9 KEV = 0.23399E-17 UCI

ROIN 5 FROM 293.0 KEV TO 299.5 KEV
PEAK AT 294.2 KEV FORM= 1.2 KEV
INTEGRAL= 457 RATE= 0.0 CPS
AREA= 223 ERR= 13.92



PR-214 AT 295.2 KEV = 0.37697E-18 UCI

ROIB 6 FROM 348.7 KEV TO 356.5 KEV
PEAK AT 353.1 KEV FUHM= 1.4 KEV
INTEGRAL= 527 RATE= 0.0 CPS
AREA= 347 ERR= 8.91

PA-133 AT 354.0 KEV = 0.10048E-03 UCI PB-214 AT 351.7 KEV = 0.37074E-18 UCI

R018 7 FR8H 508.1 KEV TO 518.9 KEV .
PEAK AT 512.2 KEV FUMM= 2.1 KEV
INTEGRAL= 346 RATE= 0.0 CP8
AREA= 199 ERR= 14.51

NA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C0-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.45442E-04 UCI

ROIS 8 FROM 579.8 KEV TO 589.0 KEV
PEAK AT 584.8 KEV FUMM= 1.2 KEV
INTEGRAL= JSS RATE= 0.0 CP8
AREA= 232 ERR= 11.4%

KR-87 AT 585.8 KEV = 0.12665E-14 WCI

ROIB 9 FROM 404.4 KEV TO 415.6 KEV
PEAK AT 410.9 KEV FUND= 1.8 KEV
INTEGRAL= 341 RATE= 0.0 CPB
AREA= 235 ERR= 11.41

XE-135 AT 408.2 KEV = 0.31403E01 UCI 31-214 AT 409.3 KEV = 0.18444E04 UCI

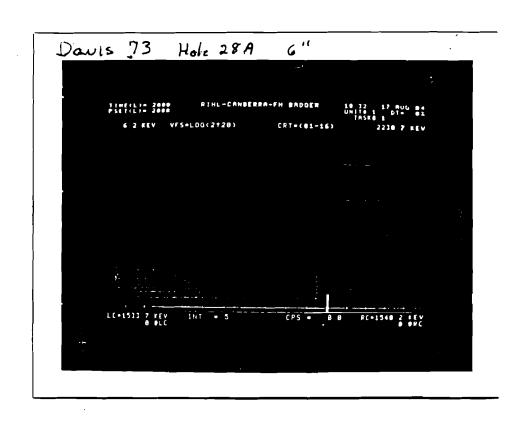
ROIS 10 FROM 438.5 KEV TO 447.8 KEV
PEAK AT 443.8 KEV FUMM= 2.4 KEV
INTEBRAL= 130 RATE= 0.0 CPS
AREA= 4 ERR= >>>>X

83-124 AT 444.2 KEV = 0.24485E-05 BCI C8-137 AT 441.4 KEV = 0.25215E-05 BCI

RGIO 11 FROM 908.4 KEV TG 914.9 KEV
PEAK AT 913.4 KEV FUMM= 1.7 KEV
INTEGRAL= 199 RATE= 0.0 CPS
AREA= 0 ERR= 0.01

ROIS 12 FROM 1454.0 KEV TO 1444.7 KEV
PEAK AT >>>>> KEV FUNN= 442.4 KEV
INTEGRAL= 481 RATE= 0.0 CP8
APF4= 0 ERR= 0.02

CHANNEL 0 BATA 71 41 40 67 96 41 55 41 47 45 73 104 47 91 124 17 100 120 174 120 121



UC BAVIB SAMPLE 873 HOLE LOCATION 28A ABOUT & INCHES 8/2/84

TAG MO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCO 1 LIVE TIME = 2000 TRUE TIME = 2002 17 AUG 94 18:29
CBLLECTED ATS 04:22:48.2 17 AUG 04

ENERGY(KEV)= 0.27048E-07 *CM^2 + 0.34313E00 *CM +0.41837E01
PEAK STATISTICS= 1.00 MIN WIDTH= 4 MAX WIDTH= 8
AREA DACKORBUND= 3 XERROR= 1.00
180 ID WINDDU= 1.0 KEV 180 ID LIDRARY= 1
AGE (DAYS)= 0.31111E01 TABLE 1

ROIB 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 24.1 KEV FORM- 0.8 KÉV
INTEGRAL- 122 RATE- 0.0 CP8
AREA- 31 ERR- 54.0X

BI-207 AT 75.0 KEY - 0.54921E-04 UCI

- ROIS 2 FRGN 87.8 KEV TO 74.3 KEV
 PEAK AT 72.3 KEV FUHH= 0.8 KEV
 INTEGRAL= 00 RATE= 0.0 CPS
 AREA= 2 ERR= >>>>X
- ROID 3 FROM 234.8 KEY TO 242.4 KEY
 PEAK AT 237.4 KEY FUMM= 2.1 KEY
 INTEBRAL= 110 RATE= 0.0 CPB
 AREA= 30 ERR= 32.0X

PD-214 AT 241.9 KEV = 0.70251E-30 UCI

ROIS 4 FROM 273.0 KEV TO 277.5 KEV
PEAK AT 275.7 KEV FUMM- 1.4 KEV
INTEGRAL- SO RATE- 0.0 CPS
AREA- 24 ERR- 41.6X

PB-214 AT 275.2 KEV - 0.15104E-30 UC1

ROIS 5 FROM 148.7 KEV TO 354.5 KEV
PEAK AT 351.7 KEV FUHN= 1.1 KEV
INTEGRAL= 52 RATE= 0.0 CPS
AREA= 52 ERR= 13.4X

PB-214 AT 351.7 KEV = 0.21812E-30 UCI



ROIR 6 FROM 508.1 KEV TO 516.7 KEV
PEAK AT 510.7 KEV FUMM= 0.7 KEV
INTEGRAL= 30 RATE= 0.0 CP8
AREA= 13 ERR= 61.52

HA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.8 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROID 7 FROM \$77.0 KEV TO \$80.4 KEV PEAK AT \$83.6 KEV FUMM= 1.5 KEV INTEDRAL= 24 RATE= 0.0 CPS AREA= 26 ERR= 17.2%

KR-87 AT 585.8 KEV = 0.27469E37 UC1

ROIG 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 407.3 KEV FMM= 2.7 KEV
INTEGRAL= 31 RATE= 0.0 CP8
AREA= 31 ERR= 14.12

XE-135 AT 408.2 KEV = 0.52435E00 UCI B1-214 AT 409.3 KEV = 0.54513E-13 UCI

ROIS 7 FROM 655.3 KEV TO 667.8 KEV
PEAK AT 661.8 KEV FUNN= 1.2 KEV
INTEGRAL= 25 RATE= 0.0 CPS
AREA= 25 ERR= 29.0Z

C8-137 AT 441.4 KEV = 0.52528E-04 UCI

ROIS 10 FROM 708.4 KEV TO 914.9 KEV
PEAK AT 911.1 KEV FUMM= 0.7 KEV
INTEGRAL= 17 RATE= 0.0 CPS
AREA= 17 ERR= 23.5%

ROID 11 FROM 1456.0 KEV TO 1464.7 KEV
PEAK AT 1460.7 KEV FUNN- 2.3 KEV
INTEGRAL- 34 RATE- 0.0 CPS
AREA- 34 ERR- 12.7%

K-40 AT 1460.8 KEV = 0.21513E-02 UCI

UC BAVIS SAMPLE 72 HOLE LOCATION 28 6INCHES DEEP (UNDER GRAVEL) 8/2/84

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ADCR 1 LIVE TIME = 2000 TRUE TIME = 2002 17 AUG 84 04:15
COLLECTED AT: 03:34:51.5 17 AUG 84

RGIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 76.8 KEV FUHH= 1.6 KEV
INTEGRAL= 129 RATE= 0.0 CPS
AREA= 51 ERR= 33.3%

BI-207 AT 75.0 KEV = 0.93645E-04 UCI

ROI8 2 FROM 89.8 KEV TO 96.3 KEV
PEAK AT 92.3 KEV FWHM= 1.6 KEV
INTEGRAL= 106 RATE= 0.0 CP8
AREA= 28 ERR= 57.1%

ROID 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.6 KEV FUHMM. 1.2 KEV
INTEGRAL= 111 RATE= 0.0 CP8
AREA= 81 ERR= 16.0X

ROIS 4 FROM 293.0 KEV TO 299.5 KEV
PEAK AT 295.5 KEV FUNN= 1.9 KEV
INTEGRAL= 39 RATE= 0.0 CP8
AREA= 26 ERR= 38.7%

PB-214 AT 293.2 KEV = 0.49847E-31 UC1

ROIR 5 FROM 348.9 KEV TO 354.5 KEV
PEAK AT 352.2 KEV FUHN= 2.7 KEV
INTEGRAL= 47 RATE= 0.0 CPS
AREA= 32 ERR= 28.11

PB-214 AT 351.9 KEV = 0.4089E-31 UCI

ROIO 4 FRON 508.1 KEV TO 514.7 KEV
PEAK AT >>>>> KEV FUNN- 501.7 KEV
INTEGRAL- 33 RATE- 0.0 CPS
AREA- 16 ERR- 54.2%

ROIS 7 FROM 527.8 KEV TO 588.4 KEV PEAK AT 583.5 KEV FURM= 1.5 KEV INTEGRAL= 25 RATE= 0.0 CPS AREA= # # ERR= >>>>

KR-87 AT 585.8 KEV = 0.34793E32 UCI

ROIB 8 FROM 406.4 KEV TO 412.9 KEV
PEAK AT 609.3 KEV FUMM= 2.3 KEV
INTEGRAL= 32 RATE= 0.0 CPS
AREA= 19 ERR= 36.8X

XE-135 AT 408.2 KEV = 0.30312E00 UCI BI-214 AT 409.3 KEV = 0.69874E-14 UCI

RDIS 9 FROM 455.3 KEV TD 467.8 KEV
PEAK AT 459.7 KEV FUMM= 4.2 KEV
INTEGRAL= 16 RATE= 0.0 CPS
AREA= 16 ERR= 25.02

RB-89 AT 457.7 KEV = 0.15444E08 UCI A0-110M AT 457.7 KEV = 0.30218E-04 UCI CS-137 AT 441.6 KEV = 0.33418E-04 UCI

RGIS 10 FROM 908.4 KEV TO 914.9 KEV
PEAK AT 910.1 KEV FUMM= 0.4 KEV
INTEGRAL= 22 RATE= 0.0 CPS
AREA= 9 ERR= 77.7%

RDIG 11 FROM 1456.0 KEV TD 1464.7 KEV
PEAK AT 1461.4 KEV FUMM= 1.9 KEV
INTEGRAL= 54 RATE= 0.0 CPS
AREA= 34 ERR= 12.9%

K-40 AT 1460.8 KEV = 0.21513E-02 UCI

CHANNEL 8				,	ATA			
123 128	7	12	17	7 18	9 7	12	13 4	13 2
154 160	tt	10	11	5 0	6 8	10 4	13 10	12
421 424 432	2 5	1	4	19	31	1 17	3 7	3 7
528 534	2 1	2 2	1 2	4 2	7 2	6	7	1
631 632 640	0 2	3	2	6 3	8 1	4	9	•
724 728 734	3	2 1	5	4	.1 .1	3	2 1	4
1054 1064 1072	1 4 2	1	1	2 0	0	1	5 1	. 6 0
1105 1112	5	1	0 1	2 1	1	7 2	4	5
1175 1200 1208 1216	0 1 0	0 1 0	1 1 2	0 1 1	0 2 1	1 2 0	0 1 0	0 0 1
1661 16641						2	4	•

UC BAVIS SAMPLES 879 AND 80 HOLE LOCATION 829 6 INCHES AND 5 FEET 8/2/84 LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BADGER PAGE 1
ADCB 1 LIVE TIME = 2000 TRUE TIME = 2001 17 AUG 84 03:31
COLLECTED AT: 02:49:34.5 17 AUG 84

ROID 1 FROM 73.0 KEV TO 77.5 KEV
PEAK AT 76.7 KEV FUHN= 1.6 KEV
INTEGRAL= 107 RATE= 0.0 CPS
AREA= 27 ERR= 55.1%

31-207 AT 75.0 KEV = 0.53249E-04 UCI

ROIS 2 FROM 87.8 KEV TO 76.3 KEV
PEAK AT >>>>> KEV FUHM= 82.2 KEV
INTEGRAL= 86 RATE= 0.0 CPS
AREA= 8 ERR= >>>>1

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.9 KEV FUNN= 1.2 KEV
INTEGRAL= 112 RATE= 0.0 CPS
AREA= 37 ERR= 45.92

ROIN 4 FRON 273.0 KEV TO 277.5 KEV
PEAK AT 275.5 KEV FUNN= 1.6 KEV
INTEGRAL= 45 RATE= 0.0 CP8
AREA= 17 ERR= 52.61

PB-214 AT 293.2 KEV - 0.10725E-31 UCI

RGIO 5 FROM 340.9 KEV TO 356.5 KEV
PEAK AT 351.9 KEV FUMM= 2.2 KEV
INTEGRAL= 39 RATE= 0.0 CP8
AREA= 24 ERR= 33.31

PB-214 AT 351.7 KEV = 0.90294E-32 UCI

ROIB 6 FRON SOS.1 KEV TO \$14.7 KEV
PEAK AT \$11.0 KEV FUNN= 3.8 KEV
INTEGRAL= 41 RATE= 0.0 CPS
AREA= 24 ERR= 37.52

NA-22 AT 311.0 KEV = 0.0E00 UCI CO-54 AT 311.0 KEV = 0.0E00 UCI CO-58 AT 311.0 KEV = 0.0E00 UCI

ROIS 7 FROM 579.8 KEV TO 508.4 KEV
PEAK AT 503.1 KEV FUMM= 2.7 KEV
INTESRAL= 34 RATE= 0.0 CPS
AREA= 17 ERR= 52.93

KR-89 AT 585.8 KEV - 0.25331E28 UCI

ROIB 8 FROM 606.4 KEV TO 612.7 KEV
PEAK AT 607.5 KEV FUMM 1.6 KEV
INTEGRAL= 35 RATE= 0.0 CPB
AREA= 22 ERR= 36.32

XE-135 AT 408.2 NEV = 0.3305E00 UCI B1-214 AT 409.3 NEV = 0.1559E-14 UCI

RGIS 7 FROM 455.3 KEV TO 447.8 KEV
PEAK AT 441.8 KEV FUNN= 1.4 KEV
1NTEGRAL= 25 RATE= 0.0 CPS
AREA= 25 ERR= 20.0%

C8-137 AT 461.6 KEV - 0.52528E-04 UCI

ROIH 10 FROM 908.4 KEV TO 914.9 KEV
PEAK AT 911.0 KEV FUMM= 4.7 KEV
INTEGRAL= 14 RATE= 0.0 CPS
AREA= 16 ERR= 25.0%

RDIS 11 FROW 1454.0 KEV TO 1444.7 KEV
PEAK AT 1440.8 KEV FUNN- 3.4 KEV
INTEGRAL- 55 RATE- 0.0 CPS
AREA- 55 ERR- 12.7%

K-40 =

UC DAVIS SAMPLES 84 AND 85 HOLE LOCATION 830 6 INCHES AND 5 FEET 8/2/84 (FMB

TAG NO. = 123 ABCW 1 LIVE TIME = RIHL-CAMBERRA-FH BABGER PAGE 2000 TRUE TIME = 2004 17 AUS 84 02:06 COLLECTED AT: 01:24:49.1 17 AUS 84

EMERGY(KEV)= 0.27048E-07 •CM-2 + 0.54313E00 •CH +0.41837E01 HAX UIDTH- 8 PEAK STATISTICS= 1.00 HIN UIDTH- 6 AREA BACKGROUND= 3 180 IB UINBOU= 3.0 KEV ZERROR= 1.00 ISO ID LIBRARY= 1 AGE (DAYS)= 0.29889E01 TABLE 1

ROIN 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.2 KEV FUHH= 1.0 KEV
INTERRAL= 111 RATE= 0.0 CPS 20 ERR= 85.0I ARFA-

BI-207 AT 75.0 KEV = 0.36723E-04 UCI

ROIM 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 93.8 KEV FUMM= 2.7 KEV
INTEGRAL= 89 RATE= 0.0 CP8
AREA= 24 ERR= 42.5%

3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.9 KEV FUMM= 1.3 KEV
INTEGRAL= 104 RATE= 0.0 CPS
AREA= 61 ERR= 22.9% RG16

ROIS 4 FROM 273.0 KEV TO 277.5 KEV PEAK AT 293.7 KEY FUNN= 1.6 KEY INTEGRAL= 44 RATE= 0.0 CP8 AREA-31 ERR= 25.8I

PB-214 AT 295.2 KEV = 0.20593E-32 UCT

ROIG 5 FROM 348.9 KEV TO 354.5 KEV PEAK AT 352.4 KEV FUHM= 1.9 KEV
INTEBRAL= 44 RATE= 0.0 CP8
AREA= 31 ERR= 29.0Z

PB-214 AT 351.9 KEV = 0.13725E-32 UCI

PB-214 m.

ROIS 4 FROM 508.1 KEV TO 514.7 KEV
PEAK AT 511.4 KEV FLAMM 1.4 KEV
INTEGRAL 38 RATE 0.0 CP8
38 ERR 15.72

MA-22 AT \$11.0 KEV = 0.0E00 UCI CO-54 AT \$11.0 KEV = 0.0E00 UCI CO-50 AT \$11.0 KEV = 0.0E00 UCI SR-65 AT \$14.0 KEV = 0.4211E-04 UCI

ROIG 7 FROM 579.8 KEV TO 568.4 KEV
PEAK AT 584.1 KEV FUMM= 2.1 KEV
INTERRAL= 23 RATE= 0.0 CPS
AREA= 6 ERR= >>>>Z

KR-89 AT 585.8 KEV = 0.12438E20 UCI

ROIB 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 409.8 KEV FUMM= 1.3 KEV
INTERRAL= 38 RATE= 0.0 CP8
AREA= 38 ERR= 15.7%

XE-135 AT 408.2 KEV = 0.51382E00 UCI BI-214 AT 409.3 KEV = 0.1509E-15 UCI

ROIB 7 FRON 455.3 KEV TO 447.8 KEV
PEAK AT 458.1 KEV FUNN- 0.8 KEV
INTEGRAL= 14 RATE- 0.0 CP8
AREA- 14 ERR= 21.42

RB-87 AT 457.7 KEV = 0.35972E05 UC1 AG-110M AT 457.7 KEV = 0.24434E-04 UCI

ROIB 10 FROM 908.4 KEV TO 914.9 KEV
PEAK AT 911.7 KEV FUMM= 1.4 KEV
1NTEDRAL= 17 RATE= 0.0 CPS
AREA= 17 ERR= 23.5%

RDIB 11 FROM 1456.0 KEV TO 1464.7 KEV
PEAK AT 1462.1 KEV FUMM= 4.2 KEV
INTEGRAL= 39 RATE= 0.0 CPB
AREA= 22 ERR= 40.9%

K-40 AT 1440.8 KEV = 0.87448E-03 UCI

CHANNEL F	BATA									
123 128	•	5	10	5 15	12	8 5	9 7	10 7		
120	,	•	•		•	•		۲ ′		
154			6	5	7	10	6	7		
160	•	10	6	9	6	5	4			
421						3	2	2		
424	1	3	5		26	24	11	4		
432	1	•	6	2						
528	6	2	٥	5 2	6 2	8	5	5		
534	2	1	0	2	2					
631								2 6		
632	1	1	0	0	9	11	9	6		
640	1	1	0	1	4	0				
724					3 6	2	•	4		
728	2	5	7	5		1	0	0		
734	1	0	0	0	0					
1056	0	2 3	2 2	0	1	2	1	5		
1064	2	3	2	Ó	Ó	0	1	1		
1072	1									
1105		1	3	0	1	3	4	10		
1112	•	3	3	1	0	1				
1195				0	0	•	•	•		
1200	2	1	0	0	0	0	0	1		
1208	0	2	1 2	0	0	2	1	0		
1214	1	1	2							
1661						1	1	0		
1664	1	1	2	4	2	2	0	0 2		
1472	•	1								
2669						0	0	0 2		
2672	1	1	4	3 4	1	3	5	2		
2480	4	4	4	4	3	0				

UC DAVIS SAMPLES 89 1 90 HOLE 31 LOCATION 6" AND 5 FEET 8/2/84 LEHR

4

TAG NG. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCG 1 LIVE TIME = 2000 TRUE TIME = 2003 17 AUG 84 00:11
COLLECTED AT: 23:15:03.1 16 AUG 84

ENERGY(KEV)= 0.27048E-07 4CH^2 + 0.54313E00 4CH +0.61837E01
PEAK STATISTICS= 1.00 HIN WIDTH= 6 HAX WIDTH= 8
AREA BACKGROUND= 3 ZERROR= 1.00
150 1D WINBOW= 3.0 KEV ISO ID LIBRARY= 1
AGE (DAYS)= 0.28974E01 TABLE 1

ROIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.0 KEV FUMM= 1.3 KEV
INTEGRAL= 94 RATE= 0.0 CPS
AREA= 42 ERR= 33.32

B1-207 AT 75.0 KEV = 0.77119E-04 WCI

ROIS 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 93.7 KEV FUNN- 2.1 KEV
INTEGRAL- 83 RATE- 0.0 CPS
AREA- 31 ERR- 45.1%

RUIS 3 FROM 234.8 KEV TU 242.4 KEV
PEAK AT 239.1 KEV FUMM- 0.9 KEV
1MTEGRAL- 94 RATE- 0.0 CPS
AREA- 51 ERR- 27.42

PB-214 AT 241.9 KEV - 0.25071E-33 UCI

ROIS 4 FROM 293.0 KEV TO 299.5 KEV
PEAK AT 296.3 KEV FUNN- 1.0 KEV
INTEGRAL- 35 RATE- 0.0 CPS
AREA- 22 ERR- 36.33

P8-214 AT 295.2 KEV = 0.48443E-34 UCI

ROIS 5 FROM 348.9 KEV TO 354.5 KEV
PEAK AT 352.7 KEV FUNN= 0.8 KEV
INTEGRAL= 46 RATE= 0.0 CPS
AREA= 31 ERR= 27.02

PB-214 AT 351.9 KEV = 0.45494E-34 UCI

ROIS 6 FRON SOS.1 KEV TO \$14.7 KEV
PEAK AT \$11.3 KEV FUNN= 2.7 KEV
INTEGRAL= 43 RATE= 0.0 CPS
AREA= 43 ERR= 13.72

MA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C8-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.70213E-04 UCI ROIS 7 FROM 579.8 KEV TO 598.4 KEV
PEAK AT 583.2 KEV FUMM= 1.1 KEV
INTEGRAL= 25 RATE= 0.0 CPS
AREA= 25 ERR= 20.0I

KR-89 AT 585.8 KEV = 0.16059E08 UCI

RGIS 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 409.8 KEV FUNN= 1.1 KEV
INTEGRAL= 21 RATE= 0.0 CPS
AREA= 21 ERR= 19.0Z

XE-135 AT 608.2 KEV = 0.24014E00 UCI B1-214 AT 609.3 KEV = 0.84831E-18 UCI

ROIS 9 FROM 455.3 KEV TO 447.8 KEV
PEAK AT 441.7 KEV FUMM 0.8 KEV
INTEGRAL= 17 RATE= 0.0 CPS
AREA= 17 ERR= 23.5%

CS-137 AT 441.4 KEV = 0.35719E-04 UCI

ROIS 10 FROM 908.4 KEV TO 914.9 KEV
PEAK AT >>>>> KEV FUMM= 902.1 KEV
INTEGRAL= 9 RATE= 0.0 CPS
AREA= 9 ERR= 33.33

ROIS 11 FROW 1454.0 KEV TO 1444.7 KEV
PEAK AT 1442.6 KEV FUHH= 2.1 KEV
INTEGRAL= 44 RATE= 0.0.CPS
AREA= 27 ERR= 33.3X

K-40 AT 1460.8 KEV = 0.10757E-02 UCI

CHANNEL &	DATA									
123				6	7	8	13	7 3		
128	6	7	14	12	6	2	3 ~	3		
154			5	6	5 3	7	9	6		
160	10	7	•	7	3	4	4			
421						3	1	2 8		
424	6	2	8	13	10	21	8	8		
432	1	2	10	1						
528	2	3 3	2	2 3	4	3	8	5		
534	0	3	0	3	0					
631								2		
632	1	1	2	2 3	5	4	12	4		
640	4	1	0	3	1	2				
924					1 '	1	2	2		
728	6	· 6	5 0	6	5	2	1	1		
136	2	1	0	t	1					
1056	0	1	. 0	1	1	1	8	4		
1064	1	1	0	1	2	0	0	1		
1072	1									
1105		2	1	1	٥	3	2	5		
1112	5	1	0	•	1	0				
1175				0	0	•	0 .	1		
1200	0	1	0	1 2	0	0	1	5		
1206	0 3	0 2	0	2	0	0	0	1		
1216	3	2	•							
1661						1	0	1		
1664	1	0	1	1	0	2	2	0		
1672	0	0								
2669				_		0	0	0		
2672	1	0	0	3	2	5	3	3		
2689	•	5		4	1	1				

UC BAVIS SAMPLES 92 & 93 HOLE BAMPLE 32 6" AND 5 FT. 8/2/84 LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER FAGE 1
ABCH 1 LIVE TINE = 2000 TRUE TINE = 2000 16 AUS 84 22:56
COLLECTED AT: 20:52:20.9 16 AUS 84

EMERGY(KEV)= 0.27048E-07 4CM-2 + 0.54313E00 4CM +0.61837E01
PEAK STATISTICS= 1.00 MIN UIDTH= 6 MAX UIBTH= 8
AREA BACKBROUND= 3 ZERROR= 1.00
150 1D LINDOU= 3.0 KEV ISO ID LIBRARY= 1
ABE (DAYS)= 0.27783E01 TABLE 1

ROIM 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.1 KEV FWMM= 2.0 KEV
INTEGRAL= 126 RATE= 0.0 CPS
AREA= 35 ERR= 51.4%

BI-207 AT 75.0 KEV - 0.44265E-04 UCI

ROIR 2 FROM 89.8 KEV TO 96.3 KEV
PEAK AT 92.5 KEV FUMM= 0.5 KEV
INTEGRAL= 107 RATE= 0.0 CP8
AREA= 16 ERR= >>>>I

ROIG 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 239.1 KEV FUMM= 1.5 KEV
INTEGRAL= 111 RATE= 0.0 CP8
AREA= 36 ERR= 47.22

PB-214 AT 241.9 KEV - 0.44155E-35 UCI

ROIS 4 FROM 273.0 KEV TO 277.5 KEV
PEAK AT 275.8 KEV FUHM= 2.9 KEV
INTEGRAL= 36 RATE= 0.0 CP8
AREA= 23 ERR= 34.72

PB-214 AT 295.2 KEV = 0.12636E-35 UCI

ROIG 5 FROM 348.9 KEV TO 356.5 KEV
PEAK AT 332.4 KEV FUMM= 1.8 KEV
INTEGRAL= 33 RATE= 0.0 CPS
AREA= 36 ERR= 23.62

PB-214 AT 351.9 KEV - 0.13914E-35 UCI

ROIS 6 FROM 508.1 KEV TO 516.7 KEV
PEAK AT 511.7 KEV FUMM- 2.8 KEV
INTEGRAL= 38 RATE= 0.0 CPS
AREA= 38 ERR= 15.72

MA-22 AT 511.0 KEV = 0.0E80 UCI C8-54 AT 511.0 KEV = 0.0E80 UCI C8-58 AT 511.0 KEV = 0.0E00 BCI SR-85 AT 514.0 KEV = 0.41983E-04 UCI ROIS 7 FROM 579.8 KEV TO 588.4 KEV
PEAK AT 583.1 KEV FUMM= 3.8 KEV
INTEGRAL= 28 RATE= 0.0 CPS
AREA= 28 ERR= 17.8%

KR-87 AT 385.8 KEV = 0.50469E-06 UCI

ROIB 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 410.0 KEV FUMM= 0.7 KEV
INTEGRAL= 31 RATE= 0.0 CP8
AREA= 31 ERR= 14.1%

XE-135 AT 408.2 KEV = 0.29543E00 UCI BI-214 AT 409.3 KEV = 0.84888E-20 UCI

ROIS 9 FROM 655.3 KEV TO 667.8 KEV
PEAK AT 659.1 KEV FUMM= 0.5 KEV
INTESRAL= 16 RATE= 0.0 CPS
AREA= 16 ERR= 25.0Z

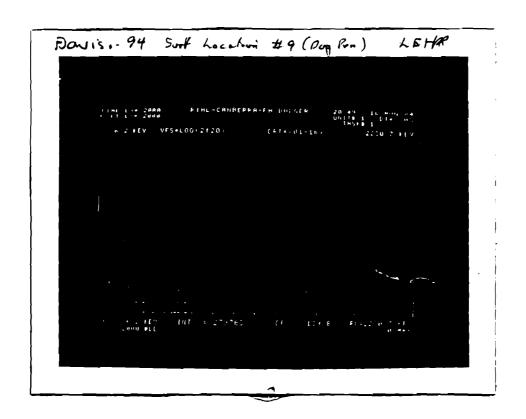
RB-87 AT 437.7 KEV = 0.15097E00 UCI AB-110H AT 457.7 KEV = 0.36194E-04 UCI CS-137 AT 441.4 KEV = 0.33417E-04 UCI

ROIS 10 FROM 708.4 KEV TO 714.7 KEV
PEAK AT 711.0 KEV FUNA- 0.8 KEV
INTEGRAL- 20 RATE- 0.0 CPS
AREA- 20 ERR- 20.0X

ROIB 11 FRON 1456.0 KEV TO 1464.7 KEV
PEAK AT 1461.4 KEV FUNN: 4.0 KEV
INTEGRAL: 50 RATE: 0.0 CPS
AREA: 50 ERR: 14.03

K-40 AT 1460.8 KEV - 0.1992E-02 UCI

CHANNEL 8		BATA									
123				10	4	7	4 ~	9			
128		12	18	15	14	8	* 75	4			
154			12	12	7 5	7 3	•	15			
160	10	7	•	5	5	3	7				
421						4	2	7			
424	1	2	7	7	18	20	14	5			
432	4	2 3	7	7							
528	Q	4	1	4	2	4	5	7			
534	1	2	1	3	2						
431								2			
432	2	3	2	0	•	10	12	2			
640	2 2	3	2	0	•	1	_				
924					•	٥	3	3			
728	2	6	4	4	•	4	1	1			
734	2 1	2	•	•	1						
1054	•	0	1	1	3 1	5 0	2	4			
1064	4	0 2	1	1	1	•	•	•			
1072	3										
1105		1	1	•	2	2	2	5			
1112	7	1 2	1 5	1	0	1					
1175				0	•	0	•	1			
1200	1	0	2	0	0	1	0	2			
1208	0	0 3	2 0	1	0	1	0	1			
1214	8										



TAG MO. = 123 RIHL-CANBERRA-FH DADGER PAGE 1
ADCO 1 LIVE TIME = 2000 TRUE TIME = 2004 14 AUG 84 18:27
COLLECTED AT 07:12:00.1 14 AUG 84

ROID 1 FROM 73.0 KEV TO 77.5 KEV
PEAK AT 76.0 KEV FUMM= 1.0 KEV
INTEGRAL= 124 RATE- 0.0 CPB
AREA- 20 ERR- 90.01

D1-207 AT 75.0 KEV = 0.34722E-04 UCI

ROIS 2 FROM 07.0 KEV TO 94.3 KEV
PEAK AT 92.3 KEV FUMM= 0.7 KEV
INTEGRAL= 103 RATE= 0.0 CPS
AREA= 12 ERR= >>>>I

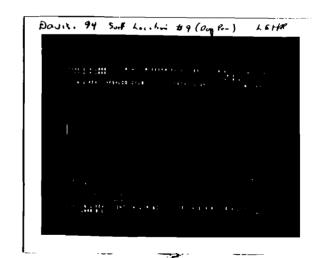
ROIN 3 FROM 234.0 KEV TO 242.4 KEV
PEAK AT 230.0 KEV FUMM- 1.6 KEV
INTEGRAL- 107 RATE- 0.0 CP8
AREA- 32 ERR- 53.11

ROIS 4 FROM 293.0 KEV TO 299.5 KEV
PEAK AT 293.1 KEV FUNM= 1.1 KEV
INTEGRAL= 43 RATE= 0.0 CP8
AREA= 30 ERR= 24.61

PB-214 AT 295.2 KEV = 0.11702E33 UC1

ROID 5 FROM 348.9 KEV TO 356.5 KEV
PEAK AT 351.0 KEV FUMM= 2.3 KEV
INTEGRAL= 47 RATE= 0.0 CP8
AREA= 47 ERR= 12.71

PD-214 AT 351.9 KEV = 0.12219E33 UCI



ROIS 4 FRON SOS.1 KEV TO 514.7 KEV
PEAK AT 510.8 KEV FUNN- 3.0 KEV
INTEGRAL- 41 RATE- 0.0 CPS
AREA- 24 ERR- 37.5%

MA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C0-58 AT 511.0 KEV = 0.0E00 UCI

ROID 7 FROM 579.8 KEV TO 588.4 KEV PEAK AT 583.7 KEV FUNN= 2.3 KEV INTEGRAL= 34 RATE= 0.0 CPB AREA= 14.7%

KR-87 AT 585.8 KEV = 0.9227E-07 UCI

ROIS 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 409.2 KEV FUMM= 1.4 KEV
INTEGRAL= 37 RATE= 0.0 CPS
AREA= 24 ERR= 33.3Z

XE-135 AT 408.2 KEV = 0.80414E-01 UCI BI-214 AT 407.3 KEV = 0.26344E-32 UCI

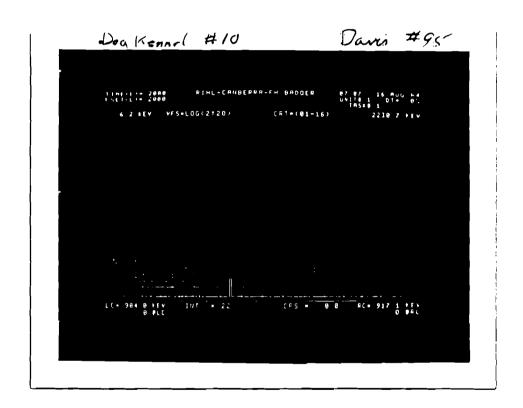
ROIS 7 FROM 455.3 KEV TO 447.8 KEV
PEAK AT 442.3 KEV FUHN- 0.5 KEV
INTEGRAL- 22 RATE- 0.0 CPS
AREA- 22 ERR- 18.11

CS-137 AT 441.4 KEV = 0.44222E-04 UCI

ROIS 10 FROM 1456.0 KEV TO 1464.7 KEV
PEAK AT 1462.0 KEV FUNM- 2.1 KEV
INTEGRAL- 50 RATE- 0.0 CPS
AREA- 58 ERR- 12.0%

K-40 AT 1440.8 KEV - 0.23107E-02 UCI

CHANNEL 0				1	DATA			
123				9	9	15	13	7
120	12	16	8	13	7	6	5	4
154			6	9	8	4	13	11
140	7	9	10	5	10	3	9	"
421						6	•	
424	3	4	2	14	15	17	2 7	4
432	3 5	•	7	4		• • •	•	•
528	1	2	2	4	11	4	1	5
536	•	2 1	2 4	2	2	•	'	•
631							•	•
432	1	1	4	4	7	7		2 2
440	•	3	4 2	Ĭ	7	ó	•	4
924					0	2	1	
728	4	4	5	7	1	ī	ė	5
736	2	2	0	7	2	·	•	•
1056	0	1	٥	1	3	2	5	
1044	0	4	0 2	i	ō	ī	1	2
1072	1				•	•	•	•
1105		1	2	•	4	5	•	,
1112	5	1	2 0	ĭ	ĩ	ĭ	,	,
1175				•	1	1	•	_
1200	•	2	1	1 2 1	;	i	0	2
1206	3	2 1 1	i	ī	2	ò	ŏ	1
1216	0	1	f	•	•	•	•	v
2449						0	•	
2672	2' 7	1	4	5	5	5	3	.0
2480	7	7	5	ŏ	5	5	J	11
•				-	-	•		



UC DAVID SAMPLE 875 SURFACE SAMPLE LOCATION 810 (BGG PENS) 8/2/84 LEHR

TAG NO. = 123 RIML-CAMBERRA-FH BADGER PAGE 1
ABCS : LIVE TIME = 2000 TRUE TIME = 2004 16 AUG 04 07:05
COLLECTES ATD 04:10:59.9 14 AUG 04

ROIO 1 FRON 73.0 KEV TO 79.5 KEV
PEAK AT 74.6 KEV FUMM- 1.6 KEV
INTEGRAL- 127 RATE- 0.0 CPB
AREA- 34 ERR- 50.02

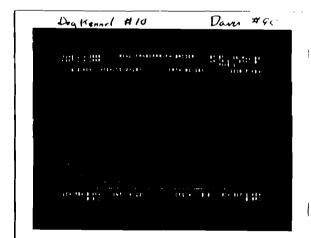
U-187 AT 72.1 KEV = 0.10327E-02 UCI H0-203 AT 72.7 KEV = 0.4584E-03 UCI D1-207 AT 72.0 KEV = 0.11594E-03 UCI

RDIO 2 FROM 07.8 KEV TO 94.3 KEV
PEAK AT 92.7 KEV FUMM- 2.7 KEV
1MTEGRAL- 70 RATE- 0.0 CP8
AREA- 30 ERR- 34.82

ROID 3 FROM 234.0 KEV TO 242.4 KEV
PEAK AT 238.0 KEV FUMM- 1.6 KEV
INTEGRAL- 117 RATE- 0.0 CPB
AREA- 72 ERR- 20.81

RGIO 4 FRON 293.0 KEV TO 299.5 KEV
-PEAK AT 295.2 KEV FWMM- 1.8 KEV
INTEGRAL- 44 RATE- 0.0 CP8
AREA- 10 ERR- 53.52

PB-214 AT 295.2 KEV = 0.17833E32 UCI



ROIS 5 FROM 348.9 KEV TO 356.5 KEV
PEAK AT 352.1 KEV FUNN= 1.6 KEV
INTEGRAL= 57 RATE= 0.0 CPS
AREA= 57 ERR= 12.2%

PB-214 AT 351.9 KEV - 0.37439E32 UC1

ROIS 6 FROM SOS.1 KEV TO 514.7 KEV
PEAK AT 510.3 KEV FUMM- 0.4 KEV
INTEGRAL- 51 RATE- 0.0 CPS
AREA- 34 ERR- 27.4X

MA-22 AT S11.0 KEV = 0.0E00 UCI C0-54 AT S11.0 KEV = 0.0E00 UCI C0-58 AT S11.0 KEV = 0.0E00 UCI

ROIR 7 FROM 577.8 KEV TO 588.4 KEV
PEAK AT 583.5 KEV FUNN= 1.4 KEV
1NTEGRAL= 24 RATE= 0.0 CP8
AREA= 24 ERR= 20.81

KR-87 AT 585.8 KEV - 0.60519E-12 UCI

ROIR 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 407.7 KEV FUMM= 1.4 KEV
INTEGRAL= 34 RATE= 0.0 CPS
AREA= 34 ERR= 14.4Z

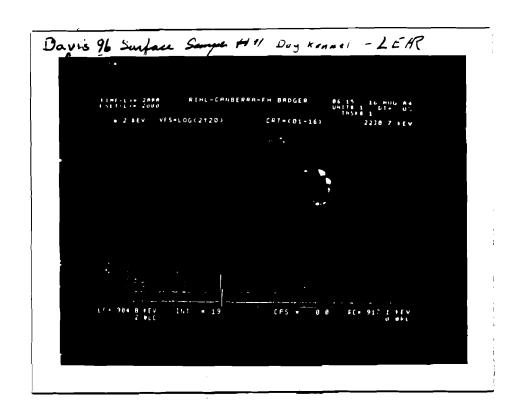
XE-135 AT 400.2 KEV = 0.11304E00 UCI BI-214 AT 409.3 KEV = 0.42437E-33 UCI

ROI8 9 FROM 455.3 KEV T8 447.8 KEV
PEAK AT 441.7 KEV FUMM 0.7 KEV
1NTEGRAL= 27 RATE= 0.0 CP8
AREA= 27 ERR= 18.51

CS-137 AT 441.4 KEV - 0.54727E-04 UCI

ROIR 10 FRON 1456.0 KEV TO 1464.7 KEV
PEAK AT 1460.9 KEV FUNN= 2.5 KEV
INTEGRAL= 67 RATE= 0.0 CPS
AREA= 67 ERR= 11.92

K-40 AT 1460.8 KEV = 0.26693E-02 UCI



UC DAVIS SAMPLE 8 94 SURFACE SAMPLE 811 8/2/84 LEHR -GRUE TIME - 2081 18 AUG 84 84:14 CBILECTED AT: 05:37:28.9 14 AUG 84

ROIO 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 74.9 KEV FUMM= 0.8 KEV
INTEGRAL= 13G RATE= 0.0 CP8
AREA= 39 ERR= 44.12

U-187 AT 72.1 KEV = 0.10745E-02 UC1 NO-203 AT 72.7 KEV = 0.47437E-03 UC2 01-207 AT 72.0 KEV = 0.1254E-01 UC1

RGIO 2 FROM 07.8 KEV TB 76.3 KEV PEAK AT 73.0 KEV FUNM- 1.7 KEV INTEDRAL- 105 RATE- 0.0 CPO AREA- 14 ERR- >>>>I

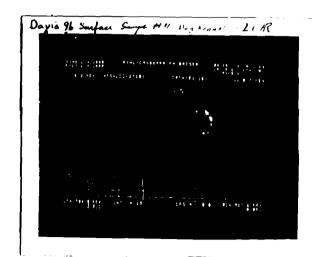
RDIO 3 FRON 234.0 KEV TO 242.4 KEV
PEAK AT 230.6 KEV FUNN- 0.9 KEV
INTEGRAL- 131 RATE- 0.0 CP8
AREA- 56 ERR- 30.37

ROID 4 FROM 273.0 NEV TD 277.5 NEV
PEAK AT 275.3 NEV FUNN= 1.0 NEV
INTEGRAL= 50 RATE= 0.0 CP8
AREA= 11 ERR= >>>>I

PD-214 AT 295.2 KEV - 0.37230E31 UCI

ROIS 5 FROM 348.9 KEV TO 336.5 KEV
PEAK AT 352.2 KEV FUHM= 1.7 KEV
INTEGRAL= 71 RATE= 0.0 CPS
AREA= 56 ERR= 17.8%

PD-214 AT 351.9 KEV = 0.12635E32 UCI



RDIB 6 FROM 508.1 KEV TO 514.7 KEV
PEAK AT 511.0 KEV FUMB 1.4 KEV
INTEGRAL 45 RATE 0.0 CPS
AREA 45 ERR 13.32

MA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C8-58 AT 511.0 KEV = 0.0E00 UCI

ROIB 7 FROM 579.8 KEV TO 588.4 KEV
PEAK AT 583.6 KEV FUMM= 1.4 KEV
INTEGRAL= 33 RATE= 0.0 CP8
AREA= 33 ERR= 15.1%

KR-87 AT 585.8 KEV = 0.74905E-16 UCI

ROIN 0 FROM 604.4 KEV TO 612.7 KEV
PEAK AT 609.8 KEV FUMM- 1.2 KEV
INTEGRAL- 42 RATE- 0.0 CP8
AREA- 29 ERR- 27.52

XE-135 AT 408.2 KEV = 0.84375E-01 UCI BI-214 AT 409.3 KEV = 0.11847E-33 UCI

ROIB 9 FROM 435.3 KEV TO 447.8 KEV
PEAK AT 441.3 KEV FURM= 0.5 KEV
INTEGRAL= 22 RATE= 0.0 CP8
AREA= 22 ERR= 18.12

CS-137 AT 441.4 KEV = 0.44222E-04 UCI

ROIS 10 FROM 1454.0 KEV TO 1444.7 KEV
PEAK AT 1440.1 KEV FUNN= 1.4 KEV
INTEBRAL= 37 RATE= 0.0 CPS
AREA= 39 ERR= 15.32

K-46 AT 1440.8 KEV = 0.15538E-02 UCI 1-135 AT=

UC BAVIS WATER SAMPLEAT RIVER DISCHARGE UNKNOWN ORIGIN ABOUT 50 GALLONS PER MINUTES

TAG NG. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ADCR 1 LIVE TIME = 2000 TRUE TIME = 2004 16 AUG 84 05:13
COLLECTED AT: 04:39:29.7 16 AUG 84

RGIE 1 FROM 73.0 KEV TO 77.5 KEV
PEAK AT 74.9 KEV FURM= 2.4 KEV
INTEGRAL= 23 RATE= 0.0 CPS
AREA= 10 ERR= 70.02

U-187 AT 72.1 KEV = 0.27338E-03 UCI H8-203 AT 72.9 KEV = 0.1272E-03 UCI BI-207 AT 72.8 KEV = 0.32204E-04 UCI

ROIS 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 92.1 KEV FUMM- 0.7 KEV
INTEGRAL- 43 RATE- 6.0 CPS
AREA- 17 ERR- 58.82

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.5 KEV FUMM- 1.5 KEV
INTEGRAL- 30 RATE- 0.0 CPS
AREA- 13 ERR- 53.32

ROIR 4 FROM 273.0 KEV TO 277.5 KEV
PEAK AT >>>>> KEV FUMM= 1.1 KEV
INTEGRAL= 14 RATE= 0.0 CP8
AREA= 1 ERR= >>>>Z

ROIS 5 FRON 348.9 KEV TO 336.5 KEV
PEAK AT >>>>> KEV FUMM= 342.5 KEV
INTEGRAL= 8 RATE= 0.0 CPS
AREA= 0 ERR= 0.02

RGIR 6 FRON SOS.1 KEV TO 516.7 KEV
PEAK AT 510.0 KEV FROM- 0.7 KEV
INTEGRAL- 28 RATE- 0.0 CPS
AREA- 28 ERR- 17.8%

MA-22 AT \$11.0 KEV = 4.0E00 UCI CO-54 AT \$11.0 KEV = 4.0E00 UCI CO-58 AT \$11.0 KEV = 4.0E00 UCI

ROIR 7 FROM \$79.0 KEV TO 588.4 KEV
PEAK AT 582.5 KEV FWM= 2.1 KEV
INTEGRAL= 14 RATE= 0.0 CPS
AREA= 14 ERR= 21.4%

ROIB 8 FROM 404.4 KEV TO 412.9 KEV
PEAK AT 410.0 KEV FUMM- 4.5 KEV
INTEGRAL- 10 RATE- 0.0 CP8
AREA- 10 ERR- 30.0Z

XE-135 AT 408.2 KEV = 4.27647E-01 UCI B1-214 AT 409.3 KEV = 0.54267E-35 UCI

ROIB 7 FROM 455.3 KEV TO 447.8 KEV
PEAK AT 440.7 KEV FUNM= 0.5 KEV
INTERRAL= 4 RATE= 0.0 CP8
AREA= 4 ERR= 33.33

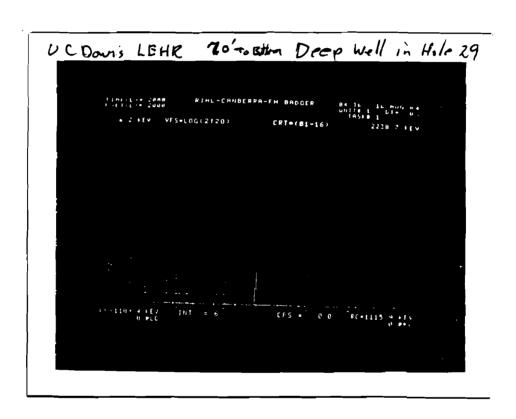
RB-89 AT 457.7 KEV = 0.30923E-20 UCI AG-110M AT 457.7 KEV = 0.11302E-04 UCI CB-137 AT 441.4 KEV = 0.12404E-04 UCI

ROIS 10 FROM 904.0 KEV TO 917.1 KEV
PEAK AT 910.1 KEV FUNN= 13.0 KEV
1NTESRAL= 7 RATE= 0.0 CPS
AREA= 7 ERR= 28.5X

ROIS 11 FROM 1456.0 KEV TO 1464.7 KEV
PEAK AT >>>>> KEV FUMM 0.8 KEV
INTEGRAL 5 RATE 0.0 CPS
AREA 5 ERR 40.0Z

ROIS 12 FROM 1739.1 KEV TO 1745.7 KEV
PEAK AT >>>>> KEV FWMM= 0.8 KEV
INTEGRAL= 1 RATE= 0.0 CPS
AREA= 1 ERR= >>>>

CHANNEL 8				De	ATA			
123 128	1	0	1	0 1	0 6	1	2 1	4 5
154 160	,	2	2 2	5 1	1 4	2 2	0 3	4
421 424 432	1	2	2	5	5	1 3	1 2	1
528 536	2	1 0	0 2	2 2	1 2	•	•	1
631 632 640	1	1	0	1 2	0 2	0	0	1 0
724 726	2	7	2	2	0	2	o 1	1
736 1956 1964	1 0 3	1 1 1	1 0 0	0 1 1	1 0	2	4	0
1072 1105	ě	, 0 3	1	•	1	1	0	1
1112 11 9 5	1		•	•	1	0	•	0
1200 1208 1216	1 2 0	0 1 0	0	0	0	2 0	0	0
1653 1656 1664 1672	• •	1 0	1 0 1	1 0 0	1 0	0 0 1 0	• •	0
2447 2472	•	•	1	•	1	0	•	0
24 00 3227 3232	•	1	•	0	0	0 0 1	0	0



TAG NO. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ADCG 1 LIVE TIME = 2000 TRUE TIME - 2003 16 AUG 84 04:35
COLLECTED ATB 04:01:02.7 16 AUG 84

ROIS 1 FROM 73.0 KEV TO 77.5 KEV
PEAK AT 74.2 KEV FUMM- 1.6 KEV
INTERRAL- 134 RATE- 0.0 CPS
AREA- 30 ERR- 40.02

U-107 AT 72.1 KEV = 0.80505E-03 UCI H0-203 AT 72.9 KEV = 0.30146E-03 UCI B1-207 AT 72.0 KEV = 0.74610E-04 UCI

ROIS 2 FROM ST.S KEV TO 78.3 KEV
PEAK AT 72.0 KEV FUHM- 3.7 KEV
INTEGRAL- 113 RATE- 0.0 CPS
AREA- 7 ERR- >>>>X

RBIB 1 FRON 234.8 KEV TB 242.4 KEV
PEAK AT 238.7 KEV FUNM- 2.2 KEV
INTEBRAL- 151 RATE- 0.0 CP8
AREA- 74 ERR- 23.42

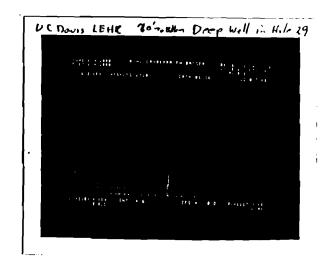
ROID 4 FRON 273.0 KEV TO 277.5 KEV
PEAK AT 275.7 KEV FWHN- 2.1 KEV
INTEGRAL- 56 RATE- 0.0 CP8
AREA- 30 ERR- 31.32

PB-214 AT 295.2 KEV - 0.83935E30 UCI

ROID 5 FRON 140.7 KEV TO 356.5 KEV
PEAK AT 352.1 KEV FURM- 2.4 KEV
INTEGRAL- 47 RATE- 0.0 CPB
AREA- 34 ERR- 26.4%

PB-214 AT 351.7 KEV - 0.43402E30 UC1





ROIS 4 FROM 508.1 KEV TO 514.7 KEV
PEAK AT 511.0 KEV FUMM= 1.4 KEV
INTEGRAL= 40 RATE= 0.0 CPS
AREA= 23 ERR= 37.1%

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

RGIN 7 FROM 579.8 KEV TO 588.4 KEV
PEAK AT 582.8 KEV FUMM= 1.0 KEV
INTEGRAL= 35 RATE= 0.0 CPS
AREA= 35 ERR= 17.1%

ROIO 8 FRON 606.4 KEV TO 612.7 KEV
PEAK AT 609.8 KEV FUMM- 0.7 KEV
INTEGRAL- 25 RATE- 0.0 CPS
AREA- 25 ERR- 20.0X

XE-135 AT 408.2 KEV = 0.45844E-01 UCI BI-214 AT 409.3 KEV = 0.35357E-35 UCI

R010 7 FROM 455.3 KEV-TO 447.8 KEV
PEAK AT 441.7 KEV FUNM= 0.7 KEV
INTEGRAL= 25 RATE= 0.0 CP8
AREA= 25 ERR= 20.02

CS-137 AT 441.4 KEV = 0.52525E-04 BC1

ROIS 10 FROM 904.0 KEV TO 917.1 KEV
PEAK AT 911.2 KEV FUNN- 2.7 KEV
INTEGRAL- 28 RATE- 0.0 CPS
AREA- 28 ERR- 17.82

ROIS 11 FROM 1434.0 KEV TO 1444.7 KEV
PEAK AT 1441.1 KEV FUNN- 3.2 KEV
INTEGRAL- 47 RATE- 0.0 CPS
AREA- 47 ERR- 11.7%

K-40 AT 1460.8 KEY - 0.26673E-02 BCI

RGIS 12 FRON 1757.1 KEV TO 1745.7 KEV
PEAK AT >>>>> KEV FUNN= 0.8 KEV
- INTEGRAL= 3 RATE= 0.0 CPS
AREA= 3 ERR= 64.42

UC BAVIS SAMPLE 8133 ASHES BUG UP BY GOPHERS IN COBALT 40 FIELD 8/4/04 LEHR

TAG NO. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ABCR 1 LIVE TIME = 2000 TRUE TIME = 2004 16 AUS 84 03:43
COLLECTED AT: 03:06:47.0 16 AUS 84

ROIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.0 KEV FUHH= 1.3 KEV
1MTEGRAL= 89 RATE= 0.0 CPS
AREA= 37.8%

BI-207 AT 75.0 KEV = 0.47935E-04 UCI

ROIB 2 FRON 89.8 KEV TO 94.3 KEV
PEAK AT 92.4 KEV FUNN- 2.8 KEV
INTEGRAL- 73 RATE- 0.0 CP8
AREA- 34 ERR- 35.22

ROIB 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.6 KEV FUNM= 1.8 KEV
INTEGRAL= 74 RATE= 0.0 CP8
AREA= 44 ERR= 27.2%

ROIE 4 FROM 293.0 KEV TO 297.5 KEV
PEAK AT 293.9 KEV FUNM= 1.0 KEU
INTEGRAL= 34 RATE= 0.0 CPS
AREA= 10 ERR= 70.02

PB-214 AT 275.2 KEV = 0.4874E29 UCI

ROID 5 FROM 348.9 KEV TO 356.5 KEV
PEAK AT 351.1 KEV FUNN- 2.7 KEV
INTEBRAL- 49 RATE- 0.0 CPS
AREA- 19 ERR- 57.81

PB-214 AT 351.9 KEV = 0.87074E29 UCI

RBIB 4 FRON 508.1 KEV TO 516.7 KEV
PEAK AT 311.2 KEV FUNM= 3.4 KEV
INTEGRAL= 41 RATE= 0.0 CPS
AREA= 41 ERR= 14.62

NA-22 AT \$11.0 KEV = 0.0E00 UCI C8-54 AT \$11.0 KEV = 0.0E00 UCI C8-58 AT \$11.0 KEV = 0.0E00 UCI \$R-65 AT \$14.0 KEV = 0.46348E-04 UCI

ROIS 7 FROM 577.8 KEV TO 588.4 KEV
PEAK AT >>>>> KEV FUHM= 373.5 KEV
INTEGRAL= 14 RATE= 0.0 CP8
AREA= 14 ERR= 21.4X

- ROIG 7 FROM 579.8 KEV TO 506.4 KEV
 PEAK AT >>>>> KEV FUMM= 573.5 KEV
 INTEGRAL= 14 RATE= 0.0 CP8
 AREA= 14 ERR= 21.4%
- ROIS 8 FROM 404.4 KEV TO 412.7 KEV
 PEAK AT 409.7 KEV FUMM= 0.7 KEV
 INTEGRAL= 24 RATE= 0.0 CPS
 AREA= 11 ERR= 43.4Z

XE-135 AT 408.2 KEV = 0.27048E-01 UCI BI-214 AT 409.3 KEV = 0.23433E-34 UCI

ROIS 9 FROM 455.3 KEV TO 447.8 KEV
PEAK AT 457.3 KEV FUNM= 1.4 KEV
INTEGRAL= 17 RATE= 0.0 CPS
AREA= 17 ERR= 23.5%

RB-89 AT 457.7 KEV = 0.1278E-21 UCI A8-110H AT 457.7 KEV = 0.32014E-04 UCI

- ROIS 10 FROM 904.0 KEV TO 917.1 KEV
 PEAK AT >>>>> KEV FWMM= 0.8 KEV
 INTEGRAL= 21 RATE= 0.0 CPS
 AREA= 21 ERR= 17.0%
- ROIS 11 FROM 1456.0 KEV TO 1464.7 KEV
 PEAK AT 1461.2 KEV FUMM= 4.1 KEU
 INTEGRAL= 52 RATE= 0.0 CPS
 AREA= 52 ERR= 13.4%

K-40 AT 1440.8 KEV = 0.20717E-02 BCI

RD18 12 FRON 1759.1 KEV TO 1745.7 KEV
PEAK AT >>>>> KEV FUMM= 0.8 KEV
INTEGRAL= 1 RATE= 0.0 CP8
AREA= 1 ERR= >>>>X

UC DAVIS SAMPLES 126.127.128. 8 129 DEEP WELL DRILLED IN HOLE 829 NUD SAMPLES @ 30.40.50.8 60 FEET LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCR 1 LIVE TINE = 2000 TRUE TINE = 2002 16 AUG 84 03:02
COLLECTED AT: 02:30:40.0 16 AUG 84

ROJE 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.0 KEV FUNN= 2.2 KEV
INTEGRAL= 141 RATE= 0.0 CPS
AREA= 37 ERR= 51.3Z

BI-207 AT 75.0 KEV # 0.67935E-04 UCI

ROIS 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 91.9 KEV FUNN= 1.7 KEV
INTEGRAL= 76 RATE= 0.0 CPS
AREA= 31 ERR= 48.3%

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.7 KEV FUNN= 1.4 KEV
INTEGRAL= 123 RATE= 0.0 CPS
AREA= 63 ERR= 25.3Z

ROIM 4 FRON 293.0 KEV TO 297.5 KEV
PEAK AT 295.4 KEV FUNN= 2.0 KEV
INTEGRAL= 37 RATE= 0.0 CP0
AREA= 24 ERR= 33.3Z

PB-214 AT 295.2 KEV - 0.64845E29 UCI

ROIS 3 FROM 348.9 KEV TO 254.5 KEV
PEAK AT 352.2 KEV FUNNO 0.8 KEV
INTEGRALO 57 RATEO 0.0 CPS
AREAO 42 ERRO 21.42

PB-214 AT 351.9 KEV - 0.75434E29 UCI

ROIS 6 FROM 508.1 KEV TO 516.7 KEV
PEAK AT 511.3 KEV FUMM- 4.3 KEV
INTEGRAL- 52 RATE- 0.0 CPS
AREA- 35 ERR- 28.52

NA-22 AT 511.0 KEV = 0.0E00 UCI C8-54 AT 511.0 KEV = 0.0E00 UCI C8-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.54424E-04 UCI

ROIS 7 FROM 579.8 KEV TO 588.4 KEV
PEAK AT 583.7 KEV FUMM= 2.7 KEV
INTEGRAL= 45 RATE= 0.0 CPS
AREA= 45 ERR= 13.3Z

ROIS 7 FROM \$79.8 KEV TO \$88.4 KEV
PEAK AT \$83.7 KEV FUNN= 2.7 KEV
INTEGRAL= 45 RATE= 0.0 CP8
AREA= 45 ERR= 13.32

KR-87 AT 585.8 KEV = 0.23723E-33 UCI

ROIS 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 410.7 KEV FUNN: 0.9 KEV
INTEGRAL= 37 RATE= 0.0 CPS
AREA= 24 ERR= 33.3%

XE-135 AT 408.2 KEV = 0.54343E-01 BCI BI-214 AT 409.3 KEV = 0.14457E-34 BCI

ROIS 7 FROM 455.3 KEV TO 447.8 KEV
PEAK AT 440.7 KEV FUNM= 7.4 KEV
INTEGRAL= 14 RATE= 0.0 CPS
AREA= 16 ERR= 25.0Z

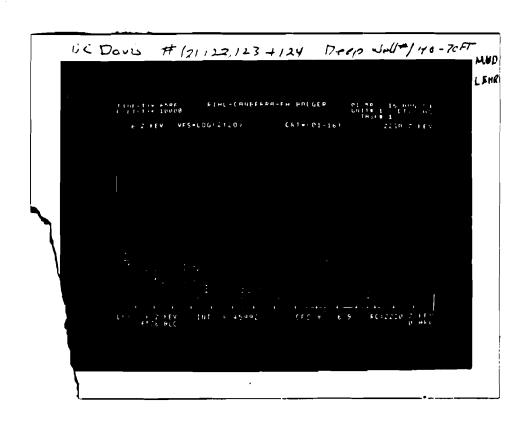
CS-137 AT 461.4 KEV - 0.33614E-04 UCI

ROIN 10 FROM 904.0 KEY TO 917.1 KEY
PEAK AT 911.5 KEY FUNN= 0.4 KEY
INTEGRAL= 23 RATE= 0.0 CPS
AREA= 0 ERR= 0.02

ROIN 11 FROM 1456.0 KEV TO 1464.7 KEV
PEAK AT 1461.9 KEV FUNN- 0.9 KEV
INTEGRAL- 47 RATE- 0.0 CPS
AREA- 47 ERR- 11.92

K-40 AT 1440.8 KEV = 0.24473E-02 UCI

ROIS 12 FROM 1757.1 NEV TO 1745.7 KEV
PEAK AT >>>>> KEV FUMM 0.8 KEV
INTEGRAL 3 RATE 0.0 CP8



UC DAVIS BAMPLES 0121.122.123. \$124 DEEP WELL 81 40 FT. TO 70 FT. IN 10 FT. INCREMENTS HUD BAMPLES LEHR

TAG NO. = 123 RIHL-CANBERRA-FH DADGER PAGE 1
ABCR 1 LIVE TIME = 4574 TRUE TIME = 4584 14 AUS 84 01:56
CGLLECTED AT4 00:03:55.4 14 AUS 84

EMERBY(NEV) = 0.27048E-07 *CM*2 + 0.54313E00 *CM *0.41837E01
PEAK STATISTICS= 1.00 MIN VIDTH= 4 MAX 818TH= 8
AREA SACKOROUND= 3 XERROR= 1.00
IBO 1D WIMDOW= 3.0 KEV IGO 1B LIBRARY= 1
ABE (BAY8) = 0.19313E01 TABLE 1

ROIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.3 KEV FOND- 0.9 KEV
INTEGRAL- 584 RATE- 0.0 CPS
AREA- 70 ERR- 44.4%

I-131 AT 00.2 KEV = 0.71532E-03 BCI BI-207 AT 75.0 KEV = 0.50257E-04 BCI

ROID 2 FROM B9.8 KEV TO 94.3 KEV PEAK AT 92.8 KEV FUMM- 1.8 KEV INTEGRAL- 425 RATE- 0.0 CP8 AREA- 100 ERR- 33.02

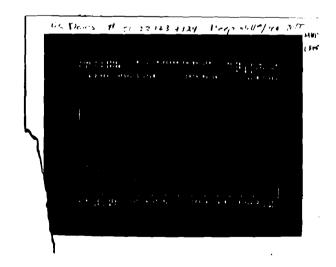
ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.7 KEV FUMM= 1.3 KEV
INTEGRAL= 474 RATE= 0.0 CPS
AREA= 176 ERR= 17.8%

ROIS 4 FROM 293.0 KEV TO 297.5 KEV
PEAK AT 295.5 KEV FUHH= 1.2 KEV
INTEGRAL= 173 RATE= 0.0 CP8
AREA= 54 ERR= 35.72

P9-214 AT 295.2 KEV - 0.10353E28 UCI

RGIO 5 FROM 340.7 KEV TO 334.5 KEV
PEAK AT 352.3 KEV FUMM= 2.4 KEV
INTEGRAL= 174 RATE= 0.0 CPO
AREA= 117 EAR= 15.7%

PB-214 AT 351.9 KEV - 0.14664E28 UCI



RGIS 6 FROM SGS.1 KEV TO \$14.7 KEV
PEAK AT \$11.6 KEV FUMM= 2.2 KEV
INTESRAL= 157 RATE= 0.0 CPS
AREA= 74 ERR= 27.02

MA-22 AT S11.0 KEV = 0.0E00 UCI C8-54 AT S11.0 KEV = 0.0E00 UCI C0-58 AT S11.0 KEV = 0.0E00 UCI SR-85 AT S14.0 KEV = 0.34371E-04 UCI

ROIG 7 FROM 579.0 KEV TO 500.4 KEV
PEAK AT 503.7 KEV FUNM= 2.2 KEV
INTEGRAL= 131 RATE= 0.0 CPS
AREA= 97 ERR= 15.4%

KR-87 AT 585.8 KEV = 0.2108E30 UCI

ROIB 8 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 407.4 KEV FUMM= 1.5 KEV
INTEGRAL= 131 RATE= 0.0 CPS
AREA= 72 ERR= 15.22

XE-135 AT 608.2 KEV = 0.54523E-01 UCI B1-214 AT 609.3 KEV = 0.11944E39 UCI

ROIS 7 FROM 458.0 KEV TO 473.7 KEV
PEAK AT 473.1 KEV FUMM= 0.5 KEV
INTEGRAL= 100 RATE= 0.0 CPS
AREA= 10 ERR= >>>>X

RBIB 10 FROM 904.0 KEV TO 917.1 KEV
PEAK AT 911.7 KEV FUMM= 1.7 KEV
INTEGRAL= 85 RATE= 0.0 CPS
AREA- 60 ERR= 21.62

ROIN 11 FROM 1454.0 KEV TO 1444.7 KEV
PEAK AT 1441.3 KEV FUMM= 4.2 KEV
INTEGRAL= 238 RATE= 0.0 CPS
AREA= 187 ERR= 10.12

K-40 AT 1440.8 KEV = 0.22458E-02 UCI

ROIG 12 FROM 1759.1 KEV TO 1745.7 KEV
PEAK AT >>>>> KEV FUND 115.0 KEV
INTEGRAL 14 RATE 0.0 CP8
AREA 3 ERR >>>>X

UC DAVIS SAMPLE 8/5117.118.119. 2120 DEEP WEL 81 START TO 30 FT IN TEN FT INCREMENTS NUB SAMPLES LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ADCH 1 LIVE TIME = 9985 TRUE TIME = 10000 15 AUS 84 21:03
COLLECTED AT: 08:39:38.4 15 AUS 84

EMERGY(KEV)= 0.27048E-07 **CM^2 + 0.54313E00 **CM + 0.41837E01 **PEAK STATISTICS= 1.00 **MIN UIBTH= 4 **MAX UIBTH= 6 **AREA BACKGROUMB= 3 **ZERROR= 1.00 **ISO ID UINBOU= 3.0 KEV 180 ID LIBRARY= 1 **ABLE 1 **ABLE 1

RGIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 74.6 KEV FUMMS 0.7 KEV
INTESRALS 236 RATES 0.0 CPS
AREAS 74 ERRS 33.7%

U-187 AT 72.1 KEV = 0.22491E-03 UCI HG-203 AT 72.7 KEV = 0.18422E-03 UCI BI-207 AT 72.8 KEV = 0.47735E-04 UCI

ROIB 2 FROM 87.8 KEV TO 94.3 KEV
PEAK AT 92.4 KEV FUNN= 1.1 KEV
INTEGRAL= 234 RATE= 0.0 CP8
AREA= 52 ERR= 48.03

ROID 3 FROM 234.6 KEV TO 242.4 KEV
PEAK AT 238.8 KEV FUNN= 1.1 KEV
INTEGRAL= 228 RATE= 0.0 CP8
AREA= 108 ERR= 21.22

ROIS 4 FROM 348.7 KEV TO 356.5 KEV
PEAK AT 352.0 KEV FUNN= 1.2 KEV
INTEGRAL= 78 RATE= 0.0 CP8
AREA= 23 ERR= 67.51

PP-214 AT 351.9 KEV = 0.77798E16 UCI

ROID S FROM SOB.1 KEV TO 514.7 KEV
PEAK AT 511.1 KEV FUNN= 2.8 KEV
INTEGRAL= 151 RATE= 0.0 CP8
AREA= 100 ERR= 17.0%

MA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 BCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROID 6 FROM 577.8 KEV TO 508.4 KEV
PEAK AT 503.0 KEV FUNN- 0.8 KEV
'INTEGRAL- 63 RATE- 0.0 CP8
AREA- 12 ERR- >>>>

KR-87 AT 585.8 KEV - 0.34733E18 UCI

ROIS 6 FROM 577.8 KEV TO 588.4 KEV
PEAK AT 583.0 KEV FUNN- 0.8 KEV
INTEGRAL~ 63 RATE~ 0.0 CPS
AREA~ 12 ERR= >>>>I

KR-89 AT 585.8 KEV = 0.34733E18 UCI

ROIS 7 FROM 604.4 KEV TO 612.9 KEV
PEAK AT 609.8 KEV FUMM= 1.0 KEV
INTEGRAL= 49 RATE= 0.0 CPS
AREA= 23 ERR= 43.4%

XE-135 AT 408.2 KEV = 0.27702E-02 UCI BI-214 AT 409.3 KEV = 0.20425E24 UCI

RGIS 8 FROM 640.7 KEV TO 673.7 KEV
PEAK AT 661.8 KEV FUNN= 1.7 KEV
INTEGRAL= 49 RATE= 0.0 CPB
AREA= 0 ERR= 0.0%

CS-137 AT 661.6 KEV = 0.0E00 UCI

ROIN 9 FRON 1454.0 KEV TO 1444.7 KEV
PEAK AT 1459.4 KEV FUNM= 4.6 KEV
INTEGRAL= 38 RATE= 0.0 CPS
AREA= 21 ERR= 42.8%

K-40 AT 1460.8 KEV = 0.16758E-03 UCI I-135 AT 1457.6 KEV = 0.52162E-02 UCI

ROIS 10 FRON 1757.1 KEV TO 1745.7 KEV
PEAK AT 1743.1 KEV FUMM= 0.8 KEV
INTEGRAL= 7 RATE= 0.0 CPS
AREA= 7 ERR= 33.32

BI-214 AT 1764.5 KEV = 0.19236E25 UCI

CHANNEL &	DATA								
123				14	17	19 13	34 14	1 6 13	
128	28	21	23	25	17	13	14	13	
154			22	14	13	23	25	29	
160	25	14	14	15	13	7	16		
421						5	8	5	
424	5	9 8	7	26	53	32	17	15	
432	4	8	14	12					
631				_				4	
432	5 4	8 2	7	• 2	10	14	10	3	
640	4	2	4	2	10	4			
924					3	3 7	14	10	
728	25	24	17	15	14	7	4	3	
936	5	3	•	1	1				
1054	3 5	4	2 3	0 2	3 2	5	13	4	
1064	5	2	3	2	2	4	3	2	
1072	4								
1105		3 3	3	2	4 2	2	4	12	
1112	7	3	0	4	2	1			
1205						1	5	4	
1208	6	1	4	1	1	1	1	2	
1216	· 4	2	2	1	1	0	1	1	
1224	2	1	1	2	2	0			
2669			•			0	0	2 2	
2472	3	2	5 5	1	3	2 2	4	2	
2480	•	1	5	4	0	2			
3227				0	0	0 2	0 2	1	
3232	0	0	2	1	0	2	2	1	

UC BAVIS SAMPLE 8132 SEDIMENT AT UNKNOWN LIQUED EFFLUENT DISCHARGE & RIVER

TAG MG. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ADCH ! LIVE TIME = 9987 TRUE TIME = 10000 14 AUG 84 21:35
COLLECTED AT: 05:235:46.7 14 AUG 84

ENERGY(KEV)= 0.27048E-07 °CN^2 + 0.54313E00 °CN +0.61837E01
PEAK STATISTICS= 1.00 MIN WIDTH= 6 MAX WIDTH= 8
AREA BACKGROUMB= 3 ZERROR= 1.00
ISO ID WINDOW= 3.0 KEV ISO ID LIDRARY= 1
AGE (BAYS)= 0.16177E00 TABLE 1

ROIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 74.5 KEV FUNM= 1.4 KEV
INTEGRAL= 714 RATE= 0.0 CPS
AREA= 181 ERR= 23.7%

BI-207 AT 75.0 KEV = 0.44546E-04 UC1

- ROIS 2 FROM 89.8 KEV TO 94.3 KEV
 PEAK AT 92.3 KEV FUNN= 2.1 KEV
 INTEGRAL= 541 RATE= 0.0 CP8
 AREA= 86 ERR= 45.3Z
- ROIS 3 FROM 136.0 KEY TO 148.5 KEV
 PEAK AT 146.8 KEV FUNN= 1.5 KEV
 INTEGRAL= 700 RATE= 0.0 CPS
 AREA= 0 ERR= 0.02

CE-141 AT 145.4 KEV = 0.0E00 UCI

ROIR 4 FROM 177.2 KEV TO 189.8 KEV
PEAK AT 185.7 KEV FUNN- 2.6 KEV
INTEGRAL- 659 RATE- 0.0 CP8
AREA- 11 ERR- >>>>

U-235 AT 185.7 KEV - 0.19113E-05 UCI

- ROIS 5 FROM 234.8 KEV TO 242.4 KEV
 PEAK AT 238.6 KEV FUNN= 1.4 KEV
 INTEGRAL= 636 RATE= 0.0 CPS
 AREA= 246 ERR= 16.2X
- ROIS 4 FROM 291.9 KEV TS 298.4 KEV
 PEAK AT 293.4 KEV FUMM» 2.3 KEV
 INTEGRAL= 237 RATE= 0.0 CPS
 AREA® 114 ERR= 20.11

PB-214 AT 295.2 KEV = 0.3357E-01 UC1

ROIS 7 FROM 234.2 KEV TS 243.5 KEV
PEAK AT 238.4 KEV FUMM= 1.5 KEV
INTEGRAL= 203 RATE= 0.0 CPS
AREA= 57 ERR= 42.3X

CS-136 AT 340.6 KEV . 0.21007E-04 UCI

RDIS B FROM 348.9 KEV TO 356.0 KEV PEAK AT 352.1 KEV FURMS 1.7 KEV ROIS 8 FROM 348.7 KEV TO 356.0 KEV
PEAK AT 352.1 KEV FUMM= 1.7 KEV
INTEGRAL= 327 RATE= 0.0 CPS
AREA= 215 ERR= 11.1%

PB-214 AT 351.9 KEV = 0.42197E-01 UCI

ROIB 7 FRON 503.7 KEV TO 517.8 KEV
PEAK AT 510.9 KEV FUMM= 3.5 KEV
INTEBRAL= 250 RATE= 0.0 CP8
AREA= 142 ERR= 19.0Z

NA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C0-58 AT 511.0 KEV = 0.0E00 UCI

ROIS 10 FRON 577.8 KEV TO 587.4 KEV
PEAK AT 583.3 KEV FUMM= 1.4 KEV
INTERRAL= 151 RATE= 0.0 CPS
AREA= 71 ERR= 18.41

KR-89 AT 365.8 KEV - 0.23431E19 UCI

ROIS 11 FRON 404.4 KEV TO 412.7 KEV
PEAK AT 409.4 KEV FURMS 2.1 KEV
INTESRALS 190 RATES 0.0 CPS
AREAS 138 ERRS 12.3Z

XE-135 AT 408.2 KEV = 0.21041E-02 UCI BI-214 AT 409.3 KEV = 0.34105E00 UCI

ROIS 12 FRON 454.7 KEV TO 448.8 KEV
PEAK AT 442.4 KEV FUMM= 3.3 KEV
INTEGRAL= 132 RATE= 0.0 CP8
AREA= 51 ERR= 43.1Z

CS-137 AT 661.6 NEV = 0.21455E-04 UCI

ROIS 13 FROM 718.8 KEY TO 732.9 KEY
PEAK AT 725.3 KEY FUMM- 2.7 KEV
INTEGRAL- 115 RATE- 0.0 CPB
AREA- 34 ERR- 41.72

ZR-75 AT 724.2 KEV = 0.28464E-04 UCI : 88-124 AT 722.8 KEV = 0.11432E-03 UCI I-131 AT 722.9 KEV = 0.64761E-03 UCI

ROIS 14 FROM 903.5 KEV TO 917.1 KEV
PEAK AT 910.9 KEV FUNM= 3.0 KEV
INTEGRAL= 109 RATE= 0.0 CPS
AREA= 57 ERR= 31.5X

ROIS 15 FROM 742.7 KEV TO 775.2 KEV
PEAK AT 748.7 KEV FUMM- 1.0 KEV
INTEGRAL- 84 RATE- 0.0 CPS
AREA- 38 ERR- 42.1Z

ROIS 16 FROM 1114.4 KEV TO 1122.4 KEV
PEAK AT 1119.7 KEV FUMM= 4.1 KEV
INTEGRAL= 60 RATE= 0.0 CPS
AREA= 36 ERR= 27.72

TA-182 AT 1121.3 KEV = 0.57443E-84 BCI BI-214 AT 1120.3 KEV = 0.44633E00 UCI

. . . .

ROIS 17 FROM 1453.8 KEV TO 1465.2 KEV
PEAK AT 1460.5 KEV FUMM= 4.3 KEV
1MTEGRAL= 297 RATE= 0.0 CPS
AREA= 297 ERR= 5.72

K-40 AT 1460.8 KEV = 0.23676E-02 UCI 1-135 AT 1457.6 KEV = 0.43198E-02 UCI

RGIS 18 FROM 1757.0 KEV TO 1749.4 KEV
PEAK AT 1743.0 KEV FUMM= 2.0 KEV
INTEGRAL= 34 RATE= 0.0 CPS
AREA= 36 ERR= 14.62

BI-214 AT 1744.5 KEV = 0.21205E01 UCI

CHANNEL	•	BATA								
123				45	51	55	80	44		
128	40	85	74	59	42	32	23	42		
154			36	44	39	47	54	56		
160	55	43	27	41	25	32	34			
239								51		
240	26	38	25	33	32	31	27	31		
248	22	33	27	27	30	32	25	22		
254	28	27	28	31	27	23	16			
315				23	26	30	26	23		
320	25	23	27	27	14	16	20	18		
321	25	42	41	47	41	10	24	16		
334	24	30	27							
421						17	23	17		
424	17	23	40	80	123	76	40	20		
432	31	32	29	42				,		
526							14	19		
528	7	8 7	18	35	40	34	39	11		
534	11	7	10							
404					10	14	8			
402	12	10	15	17	24	15	4	12		
414	13		12	4	3	4				
631								10		
432	7	12	16	24	64	71	61	22		
640	10	5	11	7	5					

					_	_	_	_
916				_	7	7	3	3
720	2	6	4	5	5		14	14
928	23	19	26	22	25	7	3	4
736	7	7	8	5	3	3	4	
1056	4	5	6	4	14	17	20	33
1064	16	8	7	3	7	2	5	
1105		4	5	•	14	22	36	35
1112	32	12	8	3	7	1		
1194			5	6	3 3 5 4	5	•	2
1200	4	3	3	4	3	6	8	
1208	•	8	7	6	5	5	7	4
1214	4	5	1	5	4			
1312	3	4	4	4	5	2	4	5
1320	5	2	6	4 6 7	8	6	6	5 7 2
1328	t	é 2	1	7	1	5	1	2
1334	4	2	8					
1452					1	•	6	5
1454	2	1	•	5	1	1 .	4	5 7 0
1664		15	9	14	7	5	1	0
1672	2	2	1	4	3	1		
1761		4	3 3 3	4	0	3	1	3 2 5
1748	•	3	3	2	12		4	2
1776	2	1	3	2	2	4	1	5
1784	2							
2044					0	1	7	6
2048	5	4	7	• •	10	5	4	2
2645		1	1	•	1	3	1	6
2672	6	11	30	26	37	33	41	32
2480	26	21	9	6	3	1	•	
3223								1
3224	•	0	0	0	0	1 2	1	0
3232	•	5	2	0 7 0	0	2	4	4
3240	4	3	1	0	1			

UC BAVIS SAMPLE 897 SURFACE SAMPLE LOCATION 812) BOB PENS) 8/2/84 LEHR

TAG NO. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ADCB 1 LIVE TIME = 1000 TRUE TIME = 1000 TRUE TIME = 1000 14 AUS 84 22:15

EMERGY(KEV)= 0.27048E-07 **Ch**2 + 0.54313E00 **Ch **0.41837E01**

PEAK STATISTICS= 1.00 MIN WIDTH= 4 MAX WIDTH= 8

AREA BACKGROUND= 3 XERROR= 1.00

ISO IB WINBOW= 3.0 KEV ISO ID LIBRARY= 1

AGE (BAYS)= 0.83508E00 TABLE 1

My X hours

ROIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 74.7 KEV FUHN= 1.4 KEV
INTEGRAL= 63 RATE= 0.0 CPS
AREA= 11 ERR= >>>>Z

BI-207 AT 75.0 KEV = 0.40391E-04 UCI

- ROIS 2 FROM 89.8 KEV TO 94.3 KEV
 PEAK AT >>>>> KEV FUMM= 104.2 KEV
 IMTESRAL= 51 RATE= 0.0 CPS
 AREA= 0 ERR= 0.0X
- ROIS 3 FROM 134.0 KEV TO 148.5 KEV
 PEAK AT 139.5 KEV FUMM= 2.2 KEV
 INTEGRAL= 53 RATE= 0.0 CPS
 AREA= 29 ERR= 41.33

C8-57 AT 134.5 KEV = 0.22534E-03 UCI

- ROIS 4 FROM 177.3 KEV TO 187.8 KEV
 PEAK AT >>>>> KEV FUMM= 170.8 KEV
 1MTEGRAL= 48 RATE= 0.0 CPS
 AREA= 0 ERR= 0.0Z
- ROIS 5 FROM 234.8 KEV TO 242.4 KEV
 PEAK AT 238.8 KEV FUMM= 1.7 KEV
 INTEGRAL= 37 RATE= 0.0 CPS
 AREA= 22 ERR= 36.3X
- ROIS 6 FROM 271.7 KEY TO 278.4 KEY
 PEAK AT 273.2 KEV FROM: 0.7 KEV
 INTEGRAL= 15 RATE= 0.0 CPS
 AREA= 15 ERR= 24.42

PP-214 AT 295.2 KEV = 0.34114E10 UCI

ROIS 7 FROM 334.2 KEV TO 343.5 KEV
PEAK AT 334.0 KEV FUNDO 2.4 KEV
INTEGRAL= 23 RATE= 0.0 CPS
AREA= 23 ERR= 17.3X

MP-237 AT 334.2 KEV = 0.23414E-02 UCI

ROID 8 FROM 348.9 KEY TO 336.0 KEY
PEAK AT 352.4 KEY FUMM= 1.2 KEY
INTEGRAL= 26 RATE= 0.0 CP8
AREA= 26 ERR= 19.2%

P9-214 AT 351.7 KEV = 0.37413E10 UCI

ROIS 7 FROM SOJ.7 KEV TO S17.8 KEV
PEAK AT S11.7 KEV FUMM= 2.7 KEV
INTEGRAL= 23 RATE= 0.0 CPS
AREA= 23 ERR= 17.3%

MA-22 AT \$11.0 KEV = 0.0E00 UCI C0-54 AT \$11.0 KEV = 0.0E00 UCI C0-58 AT \$11.0 KEV = 0.0E00 UCI 8R-85 AT \$14.0 KEV = 0.73471E-04 UCI

ROIS 10 FRON 579.8 KEV TO 587.4 KEV
PEAK AT 583.3 KEV FWMM= 1.5 KEV
INTESRAL= 16 RATE= 0.0 CP8
AREA= 16 ERR= 25.02

KR-87 AT 585.8 KEV = 0.40366E34 UCI

ROIS 11 FROM 606.4 KEV TO 612.7 KEV
PEAK AT >>>>> KEV FUMM= 600.1 KEV
INTEGRAL= 15 RATE= 0.0 CPS
AREA= 15 ERR= 24.62

RGIS 12 FROM 654.7 KEV TO 648.8 KEV
PEAK AT >>>>> KEV FUMM= 0.8 KEV
INTEGRAL= 4 RATE= 0.0 CPS
AREA= 4 ERR= 50.02

ROIS 13 FROM 718.8 KEV TO 732.9 KEV
PEAK AT >>>>> KEV FURM= 0.8 KEV
INTEGRAL= 11 RATE= 0.0 CPS
AREA= 11 ERR= 27.2%

ROIS 14 FROM 903.5 KEV TS 917.1 KEV
PEAK AT 911.7 KEV FUMM= 3.3 KEV
INTEGRAL= 13 RATE= 0.0 CPS
AREA= 13 ERR= 23.02

RBIB 15 FROM 942.7 KEV TO 973.2 KEV
PEAK AT 945.4 KEV FUMM= 0.5 KEV
INTEGRAL= 8 RATE= 0.0 CP8
AREA= 8 ERR= 37.52

ROIS 14 FRON 1114.4 KEV TO 1122.4 KEV
PEAK AT >>>>> KEV FUND 1110.3 KEV
INTESRAL= 4 RATE= 0.0 CPS
AREA= 4 ERR= 33.32

RGIS 17 FROM 1453.8 KEV TO 1445.2 KEV
PEAK AT 1440.5 KEV FUNN= 2.2 KEV
INTEGRAL= 20 RATE= 0.0 CPB
AREA= 20 ERR= 20.01

K-40 AT 1460.8 KEV = 0.15736E-02 BCI 1-135 AT 1457.6 KEV = 0.15811E-01 BCI

ROIS 18 FROM 1757.0 KEV TO 1748.4 KEV
PEAK AT >>>>> KEV FUMM= 0.8 KEV
INTEGRAL= 1 RATE= 0.0 CPS
AREA= 1 ERR= >>>>Z

UC DAVIS SAMPLE 8 98 SURFACE SAMPLE LOCATION 813 (NE CORNER) 8/2/84 LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ADCR 1 LIVE TIME = 1998 TRUE TIME = 2000 14 AUG 84 22:59
COLLECTED AT: 22:24:03.9 14 AUG 84

ROIS 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 75.6 KEV FUMM= 3.7 KEV
INTEGRAL= 154 RATE= 0.0 CPS
AREA= 37 ERR= 54.0X

H8-203 AT 72.9 KEV = 0.44237E-03 UCI BI-207 AT 72.8 KEV = 0.11927E-03 UCI

- ROIB 2 FROM 89.8 KEV TO 94.3 KEV
 PEAK AT 92.3 KEV FUHM= 0.8 KEV
 INTEGRAL= 99 RATE= 0.0 CP8
 AREA= 21 ERR= 74.11
- ROIB 3 FROM 136.0 KEV TO 148.5 KEV
 PEAK AT >>>>> KEV FUMM= 127.4 KEV
 INTEGRAL= 108 RATE= 0.0 CP8
 AREA= 12 ERR= >>>>X
- ROID 4 FROM 177.3 KEV TO 189.8 KEV
 PEAK AT >>>>> KEV FUNN= 170.8 KEV
 INTEGRAL= 108 RATE= 0.0 CP8
 AREA= 0 ERR= 0.02
- ROIS 5 FROM 234.8 KEV TO 242.4 KEV PEAK AT 239.1 KEV FUMM= 0.9 KEV INTEGRAL= 132 RATE= 0.0 CPS AREA= 72 ERR= 22.2%

PB-214 AT 241.9 KEV - 0.49795E11 UCI

ROID & FROM 291.9 KEV TO 298.4 KEV
PEAK AT 293.7 KEV FUMM= 1.8 KEV
INTEGRAL= 35 RATE= 0.0 CP8
AREA= 22 ERR= 34.32

PB-214 AT 275.2 KEV - 0.48152E10 SCI

ROID 7 FROM 334.2 KEV TO 343.5 KEV
PEAK AT 338.1 KEV FUNN- 1.4 KEV
INTEGRAL- 34 RATE- 0.0 CPB
AREA- 16 ERR- 56.2X

C8-134 AT 340.4 KEV = 0.29549E-04 UCI

ROIB 8 FROM 348.7 KEV TO 356.0 KEV
PEAK AT 352.2 KEV FUMM- 1.0 KEV
INTEGRAL- 40 RATE- 0.0 CP8
AREA- 46 ERR- 17.32

PB-214 AT 351.9 KEV = 0.94977E10 UCI

RDIS 9 FRON 503.7 KEV TO 517.8 KEV
PEAK AT 511.4 KEV FUHM= 1.4 KEV
INTEGRAL= 64 RATE= 0.0 CPS
AREA= 37 ERR= 35.1%

MA-22 AT 511.0 KEV = 0.0E00 UCI C0-56 AT 511.0 KEV = 0.0E00 UCI C0-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.59172E-04 UCI

ROIS 10 FROM 377.8 KEV TO 387.4 KEV
PEAK AT 383.2 KEV FUNN= 1.0 KEV
1NTEGRAL= 27 RATE= 0.0 CPS
AREA= 12 ERR= 44.62

KR-87 AT 585.8 KEV = 0.71839E37 UCI

ROIB 11 FROM 404.4 KEV TO 412.9 KEV
PEAK AT 409.8 KEV FUNN- 0.9 KEV
INTEGRAL- 33 RATE- 0.0 CPS
AREA- 35 ERR- 17.12

XE-135 AT 408.2 KEV = 0.74277E-02 UCI BI-214 AT 407.3 KEV = 0.74782E15 UCI

ROIS 12 FROM 654.7 KEV TO 648.8 KEV
PEAK AT 661.7 KEV FUMM= 2.5 KEV
INTEGRAL= 31 RATE= 0.0 CPS
AREA= 31 ERR= 16.12

C8-137 AT 661.6 KEV - 0.65191E-04 UCI

RGIS 13 FROM 718.8 KEV TO 732.7 KEV
PEAK AT 727.8 KEV FUMM- 2.3 KEV
INTEGRAL- 17 RATE- 0.0 CPS
AREA- 19 ERR- 21.02

ROIS 14 FROM 903.5 KEV TO 917.1 KEV
PEAK AT 911.1 KEV FURM= 1.4 KEV
INTEGRAL= 27 RATE= 0.0 CPS
AREA= 27 ERR= 18.5%

ROIS 15 FROM 962.7 KEV TO 973.2 KEV
PEAK AT >>>>> KEV FUMM= 105.1 KEV
INTEGRAL= 18 RATE= 9.0 CPS
AREA= 18 ERR= 22.22

ROIS 16 FROM 1116.4 KEV TO 1122.4 KEV
PEAK AT 1119.7 KEV FUMM= 0.5 KEV
INTEGRAL= 14 RATE= 0.0 CPS
AREA= 14 ERR= 21.42

TA-182 AT 1121.3 KEV = 0.11217E-03 UCI BI-214 AT 1120.3 KEV = 0.15408E16 UCI

RGIS 17 FRON 1453.8 KEV TS 1445.2 KEV
PEAK AT 1441.1 KEV FUNN= 4.7 KEV
INTEGRAL= 43 RATE= 0.0 CPS
AREA= 43 ERR= 12.42

K-40 AT 1460.8 KEV = 0.25124E-02 UCI

RDIN 18 FROM 1737.0 NEW TO 1748.4 NEW PEAK AT 1747.3 NEW FUMM= 0.5 NEW INTEGRAL= 4 RATE= 0.0 CPS AREA= 50.01

XE-138 AT 1768.3 KEV = 0.69461E23 UCI BI-214 AT 1764.5 KEV = 0.20915E16 UCI

UC BAVIS SAMPLE 899 SURFACE SAMPLE LOCATION 814 (E OF BIOLAB) 8/2/84 LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ADCB 1 LIVE TIME = 1997 TRUE TIME = 2000 15 AUG 84 01:24
COLLECTED AT: 00:12:07-5 15 AUG 84

ROIB 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.0 KEV FUNM= 2.0 KEV
INTEGRAL= 138 RATE= 0.0 CP8
AREA= 47 ERR= 38.2X

31-207 AT 75.0 KEV - 0.86421E-04 UCI

RGIS 2 FROM 89.8 KEV TO 96.3 KEV
PEAK AT 93.2 KEV FUNN= 0.9 KEV
INTESRAL= 88 RATE= 0.0 CPB
AREA= 10 ERR= >>>>X

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.9 KEV FUMM= 1.4 KEV
INTEGRAL= 101 RATE= 0.0 CPS
AREA= 56 ERR= 25.01

ROIS 4 FROM 291.7 KEV TO 278.4 KEV
PEAK AT 275.6 KEV FUMM= 2.6 KEV
INTEGRAL= 38 RATE= 0.0 CP8
AREA= 25 ERR= 32.02

PB-214 AT 293.2 KEV - 0.1247E12 UCI

ROIS 5 FROM 334.2 KEV TO 343.5 KEV

PEAK AT 338.4 KEV FUMM= 1.4 KEV
INTEGRAL= 52 RATE= 0.0 CP8

AREA= 34 ERR= 29.41

CB-136 AT 340.6 KEV = 0.63074E-04 UCI

ROIS 6 FRON 348.7 NEV TO 354.0 NEV
PEAK AT 352.2 NEV FUNN= 1.5 NEV
INTEGRAL= 54 RATE= 0.0 CPS
AREA= 40 ERR= 22.5%

PD-214 AT 351.9 KEY - 0.13511E12 UCI

RGIE 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.3 KEV FUMM= 1.4 KEV
INTEGRAL= 33 RATE= 0.0 CPB
AREA= 33 ERR= 15.12

MA-22 AT 511.0 KEV = 0.0E00 UCI C0-56 AT 511.0 KEV = 0.0E00 RCI ROIM 6 FROM 348.9 KET TO 356.0 KEV
PEAK AT 352.2 KTV FUNN- 1.5 KEV
INTEGRAL- 54 RATE- 0.0 CPS
AREA- 40 ERR- 22.5%

PB-214 AT 351.9 KEV - 0.13511E12 UCI

RGIS 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.3 KEV FUMM= 1.4 KEV
INTEGRAL= 33 RATE= 0.0 CPS
AREA= 33 ERR= 15.12

MA-22 AT 511.0 KEV = 0.0E00 UCI CD-54 AT 511.0 KEV = 0.0E00 UCI CD-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.52844E-04 UCI

RGIS 8 FRON 579.8 KEV TG 587.4 KEV
PEAK AT 583.2 KEV FUHH= 2.0 KEV
INTEGRAL= 25 RATE= 0.0 CP8
AREA= 25 ERR= 20.03

KR-87 AT 585.8 KEV = 0.23527E-29 UCI

ROIS 7 FRON 404.4 KEV TO 412.7 KEV
PEAK AT 407.4 KEV FUMM= 2.3 KEV
INTEGRAL= 40 RATE= 0.0 CPS
AREA= 40 ERR= 15.02

XE-135 AT 408.2 KEV = 0.12431E-01 UCI BI-214 AT 409.3 KEV = 0.37628E17 UCI

ROIS 10 FROM 1114.4 KEV TO 1122.4 KEV
PEAK AT >>>>> KEV FUNN= 0.8 KEV
INTEGRAL= 10 RATE= 0.0 CP8
AREA= 10 ERR= 30.02

ROIR 11 FRON 1453.8 KEV TO 1445.2 KEV
PEAK AT 1441.1 KEV FUNN= 4.1 KEV
INTEGRAL= 45 RATE= 0.0 CP8
AREA= 45 ERR= 12.3Z

K-40 AT 1440.8 KEV = 0.25735E-02 UCI

ROIS 12 FROM 1757.0 KEV TO 1748.4 KEV PEAK AT 1744.2 KEV FUMM= 0.5 KEV

UC DAVIS SAMPLE 8 100 SURFACE SAMPLE LOCATION 815 (NEAR SHOP) 8/2/84 LEHR

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ADCR : LIVE TIME = 1999 TRUE TIME = 2000 15 AUG 84 02:50
COLLECTED AT: 01:39:37.7 15 AUG 84

ENERGY(KEV)= 0.27048E-07 •CN-2 + 0.54313E00 •CN +0.41837E01
PEAK STATISTICS= 1.00 HIN WIDTH= 6 HAX WIDTH= 8
AREA BACKBROWNS= 3 ZERROR= 1.00
ISO ID WINDOW= 3.0 KEV ISO ID LIBRARY= 1
AGE (BAYS)= 0.9778E00 TABLE 1

RGIS 1 FRON 73.0 KEV TO 79.5 KEV
PEAK AT 77.2 KEV FUHN= 0.5 KEV
INTEGRAL= 122 RATE= 0.0 CPS
AREA= 31 ERR= 54.81

BI-207 AT 75.0 KEV = 0.54944E-04 UCI

ROIR 2 FROM 89.8 KEV TO 96.3 KEV
PEAK AT 93.0 KEV FUNM= 2.5 KEV
INTEGRAL= 74 RATE= 0.0 CP8
AREA= 35 ERR= 34.27

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 239.1 KEV FUMM= 0.8 KEV
INTEGRAL= 72 RATE= 0.0 CPS
AREA= 47 ERR= 27.7%

PB-214 AT 241.7 KEV = 0.51093E13. UCI

ROIS 4 FROM 291.9 KEV TO 298.4 KEV
PEAK AT 293.9 KEV FUNM= 1.0 KEV
INTEGRAL= 36 RATE= 0.0 CP8
AREA= 10 ERR= 90.02

PB-214 AT 275.2 KEV = 0.48493E12 UCI

ROIS 5 FROM 334.2 KEV TO 343.5 KEV
PEAK AT 339.2 KEV FUNN= 0.7 KEV
INTEGRAL= 34 RATE= 0.0 CPS
AREA= 16 ERR= 54.2%

CB-136 AT 340.6 KEV = 0.29748E-04 WCI

ROIS 6 FROM 148.7 KEV TO 336.0 KEV
PEAK AT 331.7 KEV FUMM= 1.2 KEV
INTEGRAL= 30 RATE= 0.0 CPS
AREA= 16 ERR= 43.7%

PB-214 AT 351.9 KEV = 0.51927E12 UCI

RDIN 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.0 KEV FUMM= 2.4 KEV
INTEGRAL= 40 RATE= 0.0 CP8
AREA= 40 ERR= 15.0Z

NA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C0-58 AT 511.0 KEV = 0.0E00 UCI

ROIN 8 FROM 579.8 KEV TO 387.4 KEV
PEAK AT 383.6 KEV FAMM= 3.9 KEV
INTEGRAL= 19 RATE= 0.0 CP8
AREA= 19 ERR= 21.01

KR-89 AT 585.8 KEV = 0.34589E-21 UCI

ROIS 9 FROM 606.4 KEV TS 612.9 KEV
PEAK AT 609.4 KEV FUHH= 1.9 KEV
INTEGRAL= 31 RATE= 0.0 CPS
AREA= 18 ERR= 38.8%

XE-135 AT 408.2 KEV = 0.4347E-02 UCI BI-214 AT 409.3 KEV = 0.35855E18 UCI

ROIS 10 FROM 450.9 KEV TO 472.6 KEV
PEAK AT 442.2 KEV FURM= 2.0 KEV
INTEGRAL= 50 RATE= 0.0 CPS
AREA= 50 ERR= 14.0Z

C8-137 AT 441.4 KEY - 0.10509E-03 UCI

ROIS 11 FRON 1114.4 KEV TO 1122.4 KEV
PEAK AT >>>>> KEV FUNN= 1110.3 KEV
INTEGRAL= 4 RATE= 0.0 CPS
AREA= 4 ERR= 50.0X

ROIN 12 FROM 1453.8 KEV TO 1445.2 KEV PEAK AT 1441.5 KEV FUMM- 3.3 KEV IMTEGRAL- 35 RATE- 0.0 CPS AREA- 35 ERR- 17.1%

K-40 AT 1460.8 KEV = 0.13951E-02 UCI

ROIS 13 FROM 1757.0 KEV TO 1748.4 KEV
PEAK AT 1744.2 KEV FUNN- 11.4 KEV
INTEGRAL- 3 RATE- 0.0 CPS
AREA- 5 ERR- 40.02

31-214 ATO

UC BAVIS SAMPLE 8101 SURFACE SAMPLE 816 (NEAR FRONT GATE) LEHR

TAG NO. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ADCS 1 LIVE TIME = 1979 TRUE TIME = 2000 15 AUG 84 05:06
CDLLECTEB AT: 04:31:08.2 15 AUS 84

ENERGY(KEV)= 0.27048E-07 +0.84313E00 +0.41837E01
PEAK STATISTICS= 1.00 MIN WIDTH= 6 MAX WIDTH= 8
AREA BACKSRGUND= 3 ZERROR= 1.00
1SO 1D WINDOW= 3.0 KEV ISO 1D LIDRARY= 1
ABE (DAYS)= 0.11169E01 TABLE 1

ROIN 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 74.9 KEV FUHM= 1.4 KEV
INTEGRAL= 114 RATE= 0.0 CPS
AREA= 36 ERR= 44.4%

BI-207 AT 75.0 KEV = 0.44129E-04 UCI

ROIB 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 94.8 KEV FUNN- 1.0 KEV
INTEGRAL- 74 RATE- 0.0 CP8
AREA- 22 ERR- 57.0%

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.9 KEV FUHH= 2.2 KEV
INTEGRAL= 84 RATE= 0.0 CPS
AREA= 41 ERR= 34.1%

ROIS 4 FROM 271.7 KEV TO 278.4 KEV
PEAK AT 273.7 KEV FUND: 1.3 KEV
INTEGRAL: 36 RATE: 0.0 CPS
AREA: 10 ERR: 90.02

PB-214 AT 295.2 KEV - 0.41035E14 UCI

ROIS 5 FROM 334.2 KEV TO 343.5 KEV
PEAK AT 339.1 KEV FUNN= 1.5 KEV
INTEGRAL= 29 RATE= 0.0 CPS
AREA= 29 ERR= 17.22

C8-134 AT 340.4 KEV - 0.54258E-04 UCI

ROIS 4 FROM 148.9 MEV TO 354.0 MEV
PEAK AT 351.9 MEV FUNDS 1.3 MEV
INTEGRAL 35 RATE 0.0 CPS
AREA 21 ERR 38.02

PB-214 AT 351.9 KEV = 0.57435E14 UCI

ROIS 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.7 KEV FUNN= 1.1 KEV
INTESRAL= 35 RATE= 0.0 CPS
AREA= 35 ERR= 17.1%

NA-22 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI ROIR 7 FROM 503.7 KEV TO 517.8 KEV PEAK AT 511.7 KEV FUHN= 1.1 KEV INTEGRAL= 35 RATE= 0.0 CP8 AREA= 35 ERR= 17.1%

NA-22 AT 511.0 KEV = 0.0E00 UCI C0-34 AT 511.0 KEV = 0.0E00 UCI C0-38 AT 511.0 KEV = 0.0E00 UCI SR-65 AT 514.0 KEV = 0.54097E-04 UCI

ROIB 8 FROM 577.8 KEV TO 587.4 KEV
PEAK AT 584.1 KEV FUMM= 1.4 KEV
1NTEGRAL= 24 RATE= 0.0 CP8
AREA= 77.7%

KR-87 AT 585.8 KEV = 0.33073E-05 UCI

ROIB 7 FROM 404.4 KEV TO 412.7 KEV
PEAK AT 407.4 KEV FUND 2.3 KEV
1MTEBRAL= 25 RATE= 0.0 CPB
AREA= 25 ERR= 20.0I

XE-135 AT 408.2 KEV = 0.10944E-01 UCI B1-214 AT 409.3 KEV = 0.19324E21 UCI

ROIS 10 FROM 450.9 KEV TO 472.4 KEV
PEAK AT 441.6 KEV FWMM- 2.8 KEV
INTEGRAL- 53 RATE- 0.0 CPS
AREA- 53 ERR- 13.22

C8-137 AT 661.6 KEV = 0.1114E-03 UCI

ROIS 11 FROM 1116.4 KEV TO 1122.4 KEV
PEAK AT 1120.8 KEV FUMM= 0.5 KEV
INTEGRAL= 4 RATE= 0.0 CPS
AREA= 4 ERR= 50.0Z

TA-182 AT 1121.3 KEV = 0.32003E-04 UCI BI-214 AT 1120.3 KEV = 0.15473E21 UCI

ROIN 12 FROM 1453.8 KEV TO 1445.2 KEV
PEAK AT 1460.9 KEV FUNN- 1.4 KEV
INTEGRAL- 40 RATE- 0.0 CPS
AREA- 40 ERR- 15.0Z

K-40 AT 1460.8 KEV = 0.15944E-02 UCI

ROIS 13 FROM 1737.0 KEV TG 1748.4 KEV
PEAK AT >>>>> KEV FUNN= 1750.8 KEV
INTEGRAL= 7 RATE= 0.0 CP8
AREA= 7 ERR= 28.5%

UC BAVIS SAMPLE 8182 SURFACE BAMPLE 8 L7 (FIELB BRAIN BUMP) 8/2/84 LEMR

TAG NO. = 123 RINL-CANBERRA-FN BABGER PAGE 1
ADCG 1 LIVE TIME = 1998 TRUE TIME = 2001 15 AUG 84 05:49
COLLECTED AT: 05:14:20.8 15 AUG 84

ROIN 1 FROM 73.0 KEV TO 77.5 KEV
PEAK AT 76.2 KEV FUMM= 0.8 KEV
INTEGRAL= 112 RATE= 0.0 CPS
AREA= 34 ERR= 47.0X

BI-287 AT 75.0 KEV = 0.42484E-04 UCI

ROIS 2 FROM 89.8 KEV TO 94.3 KEV PEAK AT 92.0 KEV FUNN: 0.7 KEV INTEGRAL: 70 RATE: 0.0 CPS AREA: 31 ERR: 38.7%

ROIN 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.9 KEV FUNN= 1.3 KEV
1MTEGRAL= 70 RATE= 0.0 CPB
AREA= 40 ERR= 25.0Z

RDIB 4 FROM 291.9 KEV TO 298.4 KEV
PEAK AT >>>>> KEV FUMM= 283.4 KEV
INTEGRAL= 31 RATE= 0.0 CP8
AREA= 5 ERR= >>>>X

ROIS 5 FROM 334.2 KEV TO 343.5 KEV
PEAK AT 339.6 KEV FUMMO 4.6 KEV
INTEGRAL= 36 RATE= 0.0 CPS
AREA= 10 ERR= 50.0Z

C8-136 AT 340.6 KEV = 0.33751E-04 UCI

ROIS 4 FROM 348.7 KEV TO 354.0 KEV
PEAK AT 351.7 KEV FUNN- 1.7 KEV
INTEGRAL- 44 RATE- 0.0 CPS
AREA- 30 ERR- 24.4%

PB-214 AT 351.7 KEV - 0.26432E15 UCI

ROIS 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 509.9 KEV FUNN- 1.2 KEV
INTEGRAL- 42 RATE- 0.0 CPS
AREA- 42 ERR- 14.2%

NA-22 AT 511.0 KEV = 0.0E00 UCI CD-54 AT 511.0 KEV = 0.0E00 UCI CB-58 AT 511.0 KEV = 0.0E00 UCI

ROIS 6 FROM 579.8 KEV TO 587.4 KEV
PEAK AT 583.0 KEV FUNN- 0.5 KEV
INTEBRAL- 22 RATE- 0.0 CPS
AREA- 22 ERR- 18.1%

KR-89 AT 585.8 KEV - 0.15895E00 UCI

RUIE 9 FROM 606.4 KEV TO 612.9 KEV
PEAK AT 610.0 KEV FURM= 0.9 KEV
INTEBRAL= 26 RATE= 0.0 CP8
AREA= 13 ERR= 53.0X

XE-135 AT 408.2 KEV = 0.40418E-02 UCI BI-214 AT 409.3 KEV = 0.49043E21 UCI

ROIS 10 FROM 450.9 KEV TO 472.4 KEV
PEAK AT 442.0 KEV FUMM- 1.2 KEV
INTEGRAL- 40 RATE- 0.0 CPS
AREA- 40 ERR- 15.02

CS-137 AT 661.6 KEV - 0.84119E-04 BCI

ROIS 11 FROM 1116.4 KEV TO 1122.4 KEV
PEAK AT 1118.4 KEV FUMM= 1.5 KEV
INTEGRAL= 9 RATE= 0.0 CPS
AREA= 9 ERR= 33.32

ZH-45 AT 1115.5 KEV = 0.49047E-04 UCI TA-102 AT 1121.3 KEV = 0.72234E-04 UCI BI-214 AT 1120.3 KEV = 0.1704E22 UCI

ROIS 12 FROM 1453.8 KEV TO 1445.2 KEV
PEAK AT 1460.5 KEV FUMM= 4.3 KEV
INTEGRAL= 30 RATE= 0.0 CPS
AREA= 30 ERR= 16.6%

K-40 AT 1440.8 KEV = 0.11944E-02 UCI I-135 AT 1457.4 KEV = 0.26104E-01 UCI

RBIB 13 FROM 1757.0 KEV TO 1748.4 KEV
PEAK AT >>>>> KEV FUNN= 0.8 KEV
INTEBRAL= 3 RATE= 0.0 CPS
AREA= 3 ERR= 44.42

CHANNEL &				•	ATA			
123 126	10	17	•	7 10	5	† 5	10 5	12 7
154 140	11	4	5 3	3 7	6 5	† 4	<u> </u>	5
421 424 432	4 2	2 5	5 2	6 2	14	2 17	3	2 6
526 528 536	1 1	2 2	3	2	2	4	3	1
604 608 616	1 3	0 3	4 2	2	2 5 1	1 3 1	2 2	1 2
631 632 640	0	3 1	1 2	8	• 1	10	3	2 4
716 720 728 736	0 4 0	1 2 1	0 4 0	1	1 3 2 0	0 1 2 0	0 2 2 0	1 5 3
1056 1064	2	3	0	1	1	2	4	2
1105 1112	5	3 1	3 1	2 1	2 2	1	0	4
11 07 11 92	•	1	0	0	1	2 2	0 1	0 1

UC DAVIS SAMPLE 8103 SURFACE SAMPLE LOCATION 818 (MEAR WASHBOWN PAD) 8/2/84 LEHR

TAG NO. = 123 RIHL-CAMBERRA-FH BADGER PAGE 1
ADCH ! LIVE TIME = 1978 TRUE TIME = 2000 15 AUS 84 07:01
COLLECTED AT: 04:24:08.4 15 AUS 84

RDIO 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 76.5 KEV FUMM= 2.0 KEV
INTEGRAL= 130 RATE= 0.0 CPS
AREA= 47 ERR= 30.2Z

81-207 AT 75.0 KEY = 0.86378E-04 UCI

ROID 2 FROM 07.8 KEV TO 74.3 KEV
PEAK AT 72.7 KEV FUMM= 1.5 KEV
INTEGRAL= 88 RATE= 0.0 CPS
AREA= 23 ERR= 65.2Z

ROIB 3 FROM 129.5 KEV TO 138.2 KEV
PEAK AT 130.3 KEV FUNN= 1.1 KEV
INTEGRAL= 76 RATE= 0.0 CP8
AREA= 8 ERR= >>>>X

PU-239 AT 129.0 KEV = 0.0E00 UCI

ROID 4 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.6 KEV FUMM- 1.0 KEV
INTEGRAL- 105 RATE- 0.0 CP8
AREA- 45 ERR- 35.52

RUIO 5 FROM 148.7 KEV TO 356.5 KEV
PEAK AT 352.4 KEV FUNN- 1.0 KEV
INTEGRAL- 52 RATE- 0.0 CP8
AREA- 37 ERR- 24.3%

PB-214 AT 351.9 KEV - 0.19811E16 UCI

ROIS 6 FROM 508.1 KEV TO 514.7 KEV
PEAK AT 510.2 KEV FUMM= 0.4 KEV
INTEGRAL= 41 RATE= 0.0 CP8
AREA= 24 ERR= 37.5I

MA-22 AT 511.0 KEV = 0.0E00 UCI CD-36 AT 511.0 KEV = 0.0E00 UCI CD-38 AT 511.0 KEV = 0.0E00 UCI

ROIR 7 FROM 577.8 KEV TO 588.4 KEV
PEAK AT 583.2 KEV FUNN= 1.4 KEV
INTEGRAL= 37 RATE= 0.0 CP8
AREA= 37 ERR= 16.22

KR-87 AT 585.8 KEV - 0.11293E07 UCI

ROIS S FROM 606.4 KEV TO 612.9 KEV
PEAK AT 609.6 KEV FUNN= 1.5 KEV
INTEGRAL= 27 RATE= 0.0 CPS
AREA= 27 ERR= 18.5X

XE-135 AT 400.2 KEV = 0.13713E-01 UC1 BI-214 AT 409.3 KEV = 0.11578E23 UC1

ROIN 9 FROM 640.7 KEV TO 673.7 KEV
PEAK AT >>>>> KEV FUMM= 654.3 KEV
INTEGRAL= 19 RATE= 0.0 CPS
AREA= 19 ERR= 21.0I

RGIS 10 FROM 1454.0 KEV TO 1444.7 KEV
PEAK AT 1441.5 KEV FUNN= 1.5 KEV
INTEGRAL= 43 RATE= 0.0 CPS
AREA= 43 ERR= 12.41

K-40 AT 1460.8 KEV = 0.25124E-02 UCI

CHANNEL 6 DATA

123 6 6 11 7 10 128 12 p

UC BAVIS SAMPLE #104 SURFACE BAMPLE LOCATION #19 (MEAR FIELD BRAIN SUMP) 8/2/84 LEHR

TAG NO. = 123 RINL-CAMBERRA-FN BABGER
ABCR 1 LIVE TIME = 1998 TRUE TIME = 2001 PAGE 1978 TRUE TIME = 2001 15 AUG 84 07:40 COLLECTED AT: 07:07:22.3 ENERGY(KEV) - 0.27048E-07 +CN^2 + 0.54313E00 +CN +0.41837E01 PEAK STATISTICS- 1.00 HIN WIDTH- 6 B -HTEIU XAN AREA DACKBROUND- 3 180 19 UINDOW- 3.0 KEV ZERROR- 1.00 180 IB LIBRARY= 1 ASE (DAYS)= 0.12254E01 TABLE 1 ROIO 1 FROM 73.0 KEV TO 77.5 KEV
PEAK AT 74.6 KEV FUMM= 1.4 KEV
INTEGRAL= 91 RATE= 0.0 CPS
AREA= 13 ERR= >>>>Z U-187 AT 72.1 KEV = 0.19053E-03 UC1 N0-203 AT 72.9 KEV = 0.14334E-03 UC1 DI-207 AT 72.8 KEV = 0.41908E-04 UCI ROIS 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 92.4 KEV FUNN= 0.7 KEV
INTEGRAL= 65 RATE= 0.0 CPS
AREA= 13 ERR= . >>>>2 ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 238.8 KEV FUMM= 1.1 KEV
INTEGRAL= 75 RATE= 0.0 CP8
AREA= 45 ERR= 24.62 ROIS 4 FRON 348.9 KEV TO 336.5 KEV
PEAK AT 331.8 KEV FUNN- 1.9 KEV
INTEGRAL- 41 RATE- 9.0 CPS
AREA- 26 ERR- 30.7% PB-214 AT 351.7 KEV . 0.40465E16 UCI ROIS 5 FROM 508.1 KEV TO 514.7 KEV
PEAK AT 511.2 KEV FUNM= 0.7 KEV
INTEGRAL= 35 RATE= 0.0 CPS
AREA= 18 ERR= 50.02 MA-22 AT 511.0 REV = 0.0E00 UCI C0-54 AT 511.0 REV = 0.0E00 UCI C8-58 AT 511.0 REV = 0.0E00 UCI SR-85 AT 514.0 REV = 0.28877E-04 UCI

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ROIS 6 FROM 579.8 KEV TO 588.4 KEV
PEAK AT 583.1 KEV FUMM= 1.6 KEV
INTESRAL= 23 RATE= 0.0 CPS
AREA= 23 ERR= 17.3%

KR-87 AT 585.8 KEV = 0.58102E10 UCI

ROIS 7 FROM 404.4 KEV TO 412.9 KEV
PEAK AT 409.1 KEV FUMM= 0.8 KEV
INTEGRAL= 15 RATE= 0.0 CPS
AREA= 15 ERR= 24.42

XE-135 AT 400.2 KEV = 0.80271E-02 UCI BI-214 AT 407.3 KEV = 0.27047E23 UCI

ROIS S FROM 440.7 KEV TO 473.7 KEV
PEAK AT >>>>> KEV FUMM- 454.4 KEV
INTEGRAL- 28 RATE- 0.0 CPS
AREA- 3 ERR- >>>>

ROIS 9 FROM 1456.0 KEV TO 1444.7 KEV
PEAK AT 1461.1 KEV FUMM- 2.7 KEV
INTEGRAL- 34 RATE- 0.0 CPS
AREA- 34 ERR- 14.7%

K-40 AT 1440.8 KEV = 0.13557E-02 UCI

UC DAVIS SAMPLE MES #105 SOIL SAMPLE HOLE ECCATION #13 EXCAVATED SOIL COMPOSITE LEHR

TAG NO. = 123 RIHL-CAMBERRA-FH BABGER PAGE 1
ABCG 1 LIVE TIME = 1999 TRUE TIME = 2000 15 AUG 84 08:24
COLLECTED AT: 07:44:24-5 15 AUG 84

ENERGY(KEU)= 0.27048E-07 4CH^2 + 0.54313E00 4CH +0.41837E01
PEAK STATISTICS= 1.00 NIN WIDTH= 6 MAX WIDTH= 8
AREA BACKGROUND= 3 ZERROR= 1.00
ISO IB WINDOW= 3.0 KEV ISO ID LIBRARY= 1
AGE (BAYE)= 0.12511E01 TABLE 1

ROIN 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 75.5 KEV FUMM= 4.3 KEV
INTEGRAL= 101 RATE= 0.0 CP9
AREA= 34 ERR= 41.62

H9-203 AT 72.9 KEV = 0.45226E-03 UCI B1-207 AT 72.9 KEV = 0.11599E-03 UCI

ROIS 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 92.4 KEV FUHM= 1.7 KEV
INTEBRAL= 79 RATE= 0.6 CPS
AREA= 27 ERR= 40.1%

ROIS 3 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 230.8 KEV FUMM= 2.3 KEV
INTEGRAL= 88 RATE= 0.0 CPS
AREA= 43 ERR= 32.5%

ROIS 4 FROM 348.9 KEV TO 356.5 KEV
PEAK AT 351.6 KEV FUMM= 0.9 KEV
INTEGRAL= 33 RATE= 0.0 CPS
AREA= 33 ERR= 15.1%

PB-214 AT 351.7 KEV = 0.13379E17 UCI

ROIS 5 FROM 508.1 KEV TO 514.7 KEV
PEAK AT 511.3 KEV FUNN= 1.7 KEV
INTEGRAL= 42 RATE= 0.0 CP8
AREA= 25 ERR= 34.02

MA-22 AT 511.0 KEV = 0.0E00 UCI C8-34 AT 511.0 KEV = 0.0E00 UCI C8-38 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.40128E-04 UCI ROIS 6 FROM 579.8 KEV TO 588.4 KEV
PEAK AT 583.2 KEV FUHH= 2.0 KEV
INTEBRAL= 23 RATE= 0.0 CPS
AREA= 23 ERR= 17.3%

KR-87 AT 585.8 KEV = 0.19112E14 UCI

RDIB 7 FROM 404-4 KEV TO 412-9 KEV
PEAK AT 409-5 KEV FUMM= 1.4 KEV
INTEGRAL= 24 RATE= 0.0 CP8
AREA= 24 ERR= 20.8%

XE-135 AT 608.2 KEV = 0.1346E-01 UCI B1-214 AT 609.3 KEV = 0.15726E24 UCI

ROIS 8 FROM 440.7 KEV TO 473.7 KEV
PEAK AT >>>>> KEV FUMM= 435.0 KEV
INTEGRAL= 13 RATE= 0.0 CPS
AREA= 13 ERR= 23.0%

ROIS 9 FROM 1456.0 KEV TO 1464.7 KEV PEAK AT 1461.3 KEV FURM= 1.8 KEV
INTEGRAL= 41 RATE= 0.0 CP8
AREA= 41 ERR= 14.6Z

K-40 AT 1460.8 KEV = 0.16342E-02 UCI

ROIG 10 FROM 1759.1 KEV TO 1745.7 KEV
PEAK AT 1743.5 KEV FUMM= 0.7 KEV
INTEGRAL= 4 RATE= 0.0 CPS
AREA= 33.3X

BI-214 AT 1744.5 KEV = 0.93707E24 UCI

CHANNEL B					ATA			
123				3	11	8		11
128	12	10	10	14	3	3	2	•
154			4	4	5	2	12	9
160	12	5	5	5	4	5	3	
421						2	3	2
424	0	0	4	16	14	13	10	5
432	6	4	5	4				
631								0
632	4	0 2	1	3 1	8	3	5	1
440	4	2	0	1	1	0		
924					1	3 1	2 1	3
728	2	8	7 2	6	2	1	1	1
734	1	1	2	1	•			
1056 .	1	0	0	0	1	4	5	4
1064	4	1	•	0	1	1	0	0
1072	1							
1105		0	1	0	2 1	1	•	7
1112	4	0	1	0	1	1		
1205						1	1	0
1208	0	1	1	1	1	0	0	0
1214	0 2 2	0	1	•	2	0	0	•
1224	2	•	0	0	0	0		
2669						•	•	0
2472	2 · 5	3 1	4	4	5	2	7	4
2480	5	1	1	1	2	0		
3227				0	•	0	0	0
3232	•	1	0	5	0	0	•	0

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ADCR 1 LIVE TIME = 7984 TRUE TIME = 10000 14 AUG 84 01:31
COLLECTED AT: 23:17:39.1 13 AUG 84

ROIR : FROM 23.0 KEV TO 29.5 KEV
PEAK AT 24.4 KEV FUMM= 1.1 KEV
INTEGRAL= 664 RATE= 0.0 CP8
AREA= 183 ERR= 22.42

HG-203 AT 72.1 KEV = 0.11382E03 UCI HG-203 AT 72.7 KEV = 0.598E-03 UCI BI-207 AT 72.8 KEV = 0.11816E-03 UCI

ROIR 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 92.8 KEV FUHM= 1.4 KEV
INTEGRAL= 497 RATE= 0.0 CP8
AREA= 55 ERR= 69.0X

ROIS 3 FROM 136.0 KEV TO 148.5 KEV
PEAK AT 144.6 KEV FUMM= 0.5 KEV
INTEGRAL= 582 RATE= 0.0 CP8
AREA= SER= >>>>2

CE-141 AT 145.4 KEV = 0.16154E-05 UCI U-235 AT 143.8 KEV = 0.47057E-05 UCI

ROIR 4 FROM 177.3 KEV TO 187.8 KEV
PEAK AT 184.0 KEV FUMM= 0.8 KEV
INTEGRAL= 555 RATE= 0.0 CP8
AREA= 75 ERR= 65.31

U-235 AT 185.7 KEV = 0.13035E-04 UCI

ROIS 5 FROM 234.8 KEV TO 242.4 KEV
PEAK AT 239.0 KEV FURM= 1.8 KEV
INTEGRAL= 579 RATE= 0.0 CPS
AREA= 219 ERR= 17.3%

ROIS & FROM 291.9 KEV TO 298.4 KEV
PEAK AT 275.6 KEV FUMM= 1.5 KEV
1NTEGRAL= 184 RATE= 0.0 CPS
AREA= 82 ERR= 24.31

PB-214 AT 275.2 KEV = 0.21464E-07 UCI

ROIS 7 FROM 334.2 KEV TO 343.5 KEV
PEAK AT 338.4 KEV FUNN= 1.1 KEV
INTEGRAL= 228 RATE= 0.0 CP8
AREA= 04 ERR= 27.72

C8-134 AT 340.4 KEV = 0.80401E-04 UCI

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ROIB 8 FROM 348.9 KEV TO 354.0 KEV
PEAK AT 352.4 KEV FUHM= 1.3 KEV
INTEGRAL= 232 RATE= 0.0 CP8
AREA= 120 ERR= 18.3X

PB-214 AT 351.9 KEV = 0.20935E-07 UCI

ROIS 9 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.5 KEV FUNN= 2.5 KEV
INTEGRAL= 281 RATE= 0.0 CPS
AREA= 119 ERR= 24.02

MA-22 AT 511.0 KEV = 0.0E00 UCI CO-54 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.44177E-04 UCI

RGIS 10 FROM 579.8 KEV TO 587.4 KEV
PEAK AT 583.2 KEV FUHH= 2.0 KEV
INTEGRAL= 141 RATE= 0.0 CPS
AREA= 76 ERR= 15.6%

KR-89 AT 385.8 KEV = 0.18099E31 UCI

ROIN 11 FROM 606.4 KEV TO 612.9 KEV
PEAK AT 609.6 KEV FUMM= 1.8 KEV
INTEGRAL= 151 RATE= 0.0 CP8
AREA= 99 ERR= 16.1%

XE-135 AT 408.2 KEV = 0.11107E13 UCI BI-214 AT 409.3 KEV = 0.11511E22 UCI

ROIB 12 FROM 654.7 KEV TO 648.8 KEV
PEAK AT 661.6 KEV FURM= 2.8 KEV
INTEGRAL= 133 RATE= 0.0 CP8
AREA= .52 ERR= 42.3X

C8-137 AT 461.6 KEV = 0.21708E-04 WCI

ROIS 13 FROM 903.5 KEV TO 917.1 KEV
PEAK AT 911.7 KEV FUMM= 0.8 KEV
IMTEGRAL= 115 RATE= 0.0 CPS
AREA= 89 ERR= 16.8%

ROIS 14 FRON 942.7 KEV TO 973.2 KEV
PEAK AT 949.7 KEV FUNN= 1.8 KEV
1NTEGRAL= 102 RATE= 0.0 CPS
AREA= 78 ERR= 17.9%

ROIS 15 FROM 1116.4 KEV TO 1122.4 KEV
PEAK AT 1119.3 KEV FUMM 6.0 KEV
INTEGRAL= 44 RATE- 0.0 CPS
AREA- 8 ERR- >>>X

TA-182 AT 1121.3 KEV = 0.14296E-04 BCI B1-214 AT 1120.3 KEV = 0.44643E21 UCI

RBIG 14 FROM 1453.8 KEV TO 1445.2 KEV
PEAK AT 1441.1 KEV FUNN- 3.4 KEV
INTEGRAL- 330 RATE- 0.0 CP8
AREA- 308 ERR- 6.41

K-40 AT 1440.8 KEV = 0.24581E-02 UCI

CHANNEL &					ATA			
123			,	33	42	58	79	52
128	57	58	69	69	51	36	25	33
154			47	40	42	33	47	52
160	53	44	32	29	24	23	31	
239	28	30	19	27	17	30	18	2 8 31
240 24 8	29	20	27	16	25	17	23	34
256	20	29	25	22	25	17	17	
315			÷	20	18	18	28	24
320	22	19	17	14	20	26	22	21
32 0 3 3 6	22 20	22 27	2 9 1 9	54	31	25	21	14
421						23	15	20
424	21	10	20	49	79	101	72	35
432	24	20	37	31				
526							11	
52 8 536	6 9	10	13 7	12	33	33	25	10
604 608	13	15	11	21	10 30	11 1 9	10 15	10 10
414	12	6	12	11	3	•		• •
631								5
432	•	7	16	18	23	49	42	18
440	6	8	4	13	12			
91 6 7 20	5	2	4	5	7	7 12	5 14	7 14
728	18	25	13	22	23	14	14	.4
736	1	4	4	4	7	7	2	
1056	4	5	3	8	5	11	22	24
1064	24	14	4	5	3	3	4	
1105		5	7	3	11	13	22	28
1112	25	14	10	4	4	3		
1194			4	4	1	6		5
1200 1208	1	1 10	1 2	3 3	5 4	. 11	7 5	, 5
1216	1	5	4	5	4	•	-	•
1452					•	3	3	1
1454	4	1	3 4	7 23	3	2	4	7 3
1664 1672	7	7	4	23 1	1 0 0	1 3	2	3
1741		2	2	1	4	5	4	4
1768	3	2 7 1	2 4	1 2 4	7	13	12	11
1776	4	1	1	4	1	0	•	4
1784	3							
2044		_	_		2	4	3 4	4
2048	4	3	2	4		4		2
2445	•	. 2	1	.0	2 31	7 39	1 41	2 44
2672 2680	3 42	7 27	20 20	17 15	4	94	11	14
3				•	•	-	•	

TAG NO. = 123 RIHL-CANBERRA-FH BADGER PARE 1
ADCR 1 LIVE TIME = 7982 TRUE TIME = 10000 13 AUS 84 22:31
COLLECTED AT: 21:37:46.2 13 AUG 84

ENERGY(KEV) = 0.27048E-07 *CH^2 + 0.54313E00 *CH + 0.61837E01

PEAK STATISTICS = 1.00 MIN UIDTH = 6 MAX UIDTH = 8

AREA BACKGROUND = 3 ZERROR = 1.00

ISO ID UINBOU = 3.0 KEV ISO ID LIDRARY = 1

AGE (DAYS) = 0.1878E02 TABLE 1

ROI# 1 FROM 73.0 KEV TO 79.5 KEV
PEAK AT 77.1 KEV FUHM= 1.2 KEV
INTEGRAL= 657 RATE= 0.0 CP8
AREA= 176 ERR= 23.2%

BI-207 AT 75.0 KEV = 0.44801E-04 UCI

ROI# 2 FROM 89.8 KEV TO 96.3 KEV
PEAK AT 92.5 KEV FUHH= 1.8 KEV
INTEGRAL= 525 RATE= 0.0 CPS
AREA= 109 ERR= 33.93

ROIR 3 FROM 234.8 KEV TO 242.4 KEV

PEAK AT 238.7 KEV FUHH= 1.6 KEV

INTEGRAL= 634 RATE= 0.0 CPS

AREA= 274 ERR= 14.2X

RDIS 4 FROM 291.9 KEV TO 298.4 KEV
PEAK AT 295.2 KEV FUMM= 1.5 KEV Therest INTEGRAL= 259 RATE= 9.0 CPS
AREA= 90 ERR= 27.7Z

PB-214 AT 295.2 KEV = 0.17802E-08 UCI

ROIS 5 FRON 334.2 KEV TO 343.5 KEV
PEAK AT 338.5 KEV FUMM= 1.7 KEV Thorist
INTEGRAL= 236 RATE= 0.0 CPS
AREA= 92 ERR= 27.1%

CS-134 AT 340.4 KEV = 0.87753E-04 UCI

RDIB 6 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 352.1 KEV FUNN= 1.4 KEV
INTEGRAL= 247 RATE= 0.0 CPS
AREA= 149 ERR= 14.0%

Thorrow ore

PB-214 AT 351.7 KEV = 0.17643E-08 UCI

ROIS 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.5 KEV FUNM= 3.1 KEV
INTEGRAL= 291 RATE= 0.0 CPS
AREA= 183 ERR= 14.7%

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NA-22 AT 511.0 KEV = 0.0E00 UCI C0-54 AT 511.0 KEV = 0.0E00 UCI C0-58 AT 511.0 KEV = 0.0E00 UCI SR-85 AT 514.0 KEV = 0.70973E-04 UCI

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ROIS 8 FROM 579.8 KEY TO 587.4 KEY
                                                                       -Thomas - In
             PEAK AT 583.3 KEV FUMM= 2.0 KEV
INTEGRAL= 172 RATE= 0.0 CP8
AREA= 112 ERR= 15.1%
                                                                         n,•1
                                                                        abonio Dra
               KR-87 -- AT -- 585.0 KEY -- 0.67317221 -- UC1 '
                                                                         B. 314
RDIS 9 FROM 606.4 KEV TO 612.9 KEV
PEAK AT 609.3 KEV FUHM= 1.8 KEV
INTEGRAL= 1.44 RATE= 0.0 CPS
                                   92 ERR= 17.31
             AREA-
               XE-135 AT 408.2 NEV - 0.90722E12 UC1
B1-214 AT 409.3 NEV - 0.33008E20 UC1
ROIS 10 FROM 454.7 KEV TO 448.8 KEV
PEAK AT 441.8 KEV FUHN= 0.7 KEV
INTEGRAL= 202 RATE= 0.0 CPS
                                  121 ERR= 19.0Z
             AREA=
               CS-137 AT 641.6 KEV = 0.50787E-04 UCI
ROIS 11 FROM 703.5 KEY TO 917.1 KEY
                                                                    Theriva 227
             PEAK AT 711.5 KEV FUNN= 2.3 KEV
INTEGRAL= 121 RATE= 0.0 CPS
AREA= 75 ERR= 15.7%
                                                                  Thor. 120, 214
ROIS 12 FROM 1116.4 KEV TO 1122.4 KEV
             PEAK AT 1119.2 KEV FUMM= 0.7 KEV INTEGRAL= 50 RATE= 0.0 CPS
                                   26 ERR= 34.61
             AREA=
               ##-182 #T TT21.3 NEV -- 0-46452E-04-UCI
               B1-214 AT 1120.3 KEV = 0.44797E20 UCI
ROIS 13 FROM 1453.8 KEV TO 1465.2 KEV
             PEAK AT 1440.4 KEV FUMM= 2.8 KEV
INTEGRAL= 304 RATE= 0.0 CP8
AREA= 304 ERR= 5.52
                                                                          alanow 1459 xou
                                                                                               15 Kg Her 7
               K-40 AT 1440.8 KEV = 0.24244E-02 UCI
1-135 AT 1457.6 KEV = 0.78137E10 UCI
                                                                                               1764 5' KM?
```

CHANNEL #				1	DATA			
123				39	43	47	71	43
128	47	45	73	81	50	32	36	30
154			43	38	34	40	59	62
140	34	47	38	26	23	28	31	
421						19	22	17
424 432	12 23	24 30	43 36	75 26	114	123	47	23
	23	••						
526							11	9
528 534	1 4 20	11 17	13 8	29	46	30	23	20
330	20	17	•					
604					8	13	5	5
608	10	17	13	26	25	25	13	14
616	11	14	10	8	11	8		
631								11
632	9	9	9	17	41	57	40	16
640	12	9	5	3	9			
916					1	4	6	4
920	6	3	7	6	7	7	14	7
928	28	27	35	29	18	19	11	9
736	•	5	3	7	8	4	2	
1056		4	5	3	14	24	20	34
1064	21	14	7	6	5	3	2	
1105		2 .	4	6	10	17	31	28
1112	17	•	5	3	6	5		
1194			2	4	5	3	3	0
1200	5	3	5	7	10	11	15	40
1208	17	21	5	6	4	7	5	3
1216	3	6	3	3	4			
1452					1	٥	1	1
1454	5	5	3	1	2	3	4	4
1664	•	7	17	11	12	10	6	4
1472	4	1	2	3	2	2		
2044					3	3	1	3
2048	4	12	4	8	4	4	2	2
2665		1	4	•	0	2	1	4
2672	5	9	18	27	31	50	34	40
2480	22	23	21	8	1	1	0	

UC BAVIS SUBSURFACE SOIL SAMPLES # 20,27 & 288 # 20 FT EAKHF XXX CALIF TYPE SAMPLE

TAG NO. = 123 RIHL-CANBERRA-FH BABGER PAGE 1
ABCR | LIVE TINE = 9983 TRUE TINE = 10001 14 AUS 84 04:56
COLLECTED AT: 01:50:31.8 14 AUS 84

ENERGY(KEU)= 0.27040E-07 0CH^2 + 0.54313E00 0CH +0.41837E01
PEAK STATISTICS= 1.00 MIN VIBTH= 6 MAX VIBTH= 8
AREA BACKGROUNB= 3 XERROR= 1.00
1SO ID VINSOU= 3.0 KEV ISO ID LIBRARY= 1
AGE (DAYS)= 0.53711E-02 TABLE 1

ROIR 1 FRON 73.0 KEV TO 79.5 KEV
PEAK AT 76.7 KEV FURMS 1.2 KEV
INTEGRALS 2031 RATES 0.2 CPS
AREAS 393 ERRS IB.BX

BI-207 AT 75.0 KEV = 0.14455E-03 UCI

ROIB 2 FROM 89.8 KEV TO 94.3 KEV
PEAK AT 92.8 KEV FUMM= 0.7 KEV
INTEGRAL= 1340 RATE= 0.1 CP8
AREA= 136 ERR= 49.2%

ROIN 3 FROM 136.0 KEV TO 148.5 KEV PEAK AT 145.8 KEV FUMM= 0.5 KEV INTEGRAL= 1978 RATE= 0.1 CP8 AREA= 130 ERR= 73.8%

> CE-141 AT 145.4 KEV = 0.23421E-04 UCI U-235 AT 143.8 KEV = 0.10197E-03 UCI

ROIN 4 FRON 177.3 KEV TO 189.8 KEV PEAK AT 186.0 KEV FUNN= 1.6 KEV INTEGRAL= 1781 RATE= 0.1 CPN AREA= 125 ERR= 72.82

U-235 AT 185.7 KEV = 0.2172BE-04 WCI

ROIS 5 FROM 234-8 KEV TO 242-4 KEV
PEAK AT 238.7 KEV FUNM= 1.5 KEV
INTEGRAL= 1857 RATE= 0.1 CPB
AREA= 732 ERR= 7.22

RGIS 6 FRON 271.7 KEV TS 278.4 KEV
PEAK AT 275.4 KEV FUMM= 1.5 KEV
INTEGRAL= 674 RATE= 0.0 CPS
AREA= 310 ERR= 12.2X

PB-214 AT 295.2 KEV = 0.24997E-03 UCI

ROIS 7 FROM 334.2 NEW TO 243.5 NEW PEAK AT 338.6 NEW FUMM- 1.5 NEW INTEGRAL- 617 RATE- 0.0 CPS AREA- 147 ERR- 27.5%

CS-136 AT 340.4 KEV - 0.52434E-04 UCI

ROIS 8 FROM 348.9 KEV TO 356.0 KEV
PEAK AT 352.2 KEV FUMM= 1.6 KEV
INTEGRAL= 798 RATE= 0.0 CPS
AREA= 490 ERR= 7.7%

PB-214 AT 351.9 KEV - 0.28442E-03 UCI

ROID 7 FROM 503.7 KEV TO 517.8 KEV
PEAK AT 511.0 KEV FUHM= 2.6 KEV
INTEGRAL= 548 RATE= 0.0 CPS
AREA= 244 ERR= 18.4%

MA-22 AT 511.0 KEV = 0.0E00 UCI CO-56 AT 511.0 KEV = 0.0E00 UCI CO-58 AT 511.0 KEV = 0.0E00 UCI

ROID 10 FROM 579.8 KEV TO 587.4 KEV
PEAK AT 583.4 KEV FUHH= 2.1 KEV
INTEBRAL= 455 RATE= 0.0 CP8
AREA= 305 ERR= 9.1%

KR-87 AT 585.8 KEV = 0.32489E-02 UCI

RDIB 11 FROM 606.4 KEV TO 612.7 KEV
PEAK AT 609.6 KEV FUMM= 1.8 KEV
INTEGRAL= 482 RATE= 0.0 CPB
AREA= 352 ERR= 7.62

XE-135 AT 408.2 KEV = 0.40335E-02 UCI B1-214 AT 607.3 KEV = 0.3415E-03 UCI

ROID 12 FROM 454.7 KEV TO 448.8 KEV
PEAK AT 442.2 KEV FUMM= 1.5 KEV
INTEGRAL= 279 RATE= 0.0 CP8
AREA= 43 ERR= 55.52

CS-137 AT 441.4 KEV = 0.24514E-04 BCI

RDIO 13 FROM 710.0 KEV TO 732.7 KEV
PEAK AT 727.3 KEV FUHM= 2.4 KEV
INTEGRAL= 297 RATE= 0.0 CPS
AREA= 100 ERR= 30.52

ROIS 14 FRON 903.5 KEV TO 917.1 KEV
PEAK AT 911.5 KEV FUMM- 2.4 KEV
INTEGRAL- 333 RATE- 0.0 CPS
AREA- 177 ERR- 17.3%

ROIS 15 FROM 942.7 KEV TO 973.2 KEV
PEAK AT 949.1 KEV FUMM= 2.7 KEV
1NTEGRAL= 273 RATE= 0.0 CPS
AREA= 105 ERR= 28.5%

RGIS 16 FRON 1114.4 KEV TO 1122.4 KEV
PEAK AT 1120.6 KEV FUNN- 2.0 KEV
INTEGRAL- 145 RATE- 0.0 CPS
AREA- 37 ERR- 51.3%

TA-182 AT 1121.3 KEV = 0.57028E-04 UCI B1-214 AT 1120.3 KEV = 0.18008E-03 UCI ROID 17 FROM 1453.8 KEV TO 1465.2 KEV
PEAK AT 1460.9 KEV FUNN= 3.9 KEV
1NTEGRAL= 1035 RATE= 0.1 CPB
AREA= 949 ERR= 3.6%

K-40 AT 1460.8 KEY = 0.77341E-02 UCI

ROIG 18 FROM 1757.0 KEV TO 1748.4 KEV
PEAK AT 1744.5 KEV FUMM- 3.2 KEV
INTEGRAL- 79 RATE- 0.0 CPS
AREA- 57 ERR- 21.0%

31-214 AT 1744.5 KEV = 0.1318E-02 UCI

CHANNEL I	•				BATA			
123				117	135	178	214	184
128	143	178	243	191	117	107	101	77
154			157	124	100	115	134	144
140	144	116	107	103	84	74	72	
239								85
240	84	75	87	75	79	83	71	79
248	78	79	87	87	79	76	73	85
256	73	102	81	81	48	72	77	
315				43	75	70	71	77
320	46	45	47	78	43	47	66	66
320	45	75	91	113	121	84	65	44
334	73	80	54					
421						53	52	45
424	53	57	74	219	345	324	152	63
432	74	102	102	78				
526							30	32
528	40	28	49	70	104	131	73	46
534	27	23	19					
604					32	27	21	23
408	20	31	15	60	74	74	14	24
414	35	22	25	25	24	31		
431								15
632	26	32	34	57	137	184	127	48
640	27	22	19	27	17			

914					6	11	11	11
720	12	15	12	9	19	15	17	13
720	47	62	40	54	34	14	16	15
		15	11	10	14	14	17	•
936	12	13	• • • • • • • • • • • • • • • • • • • •	,,			• • •	
1054	7	11	13	15	16	50	81	80
1964	76	32	25	17	10	10	12	
1105		12	12	14	32	52	87	104
1112	71	47	21	9	10	9	••	
1194			10	11	4	12	11	14
1200	. 8	10	8	4	•	11	11	17
1200	15	13	9	4	9	12	11	14
1216	9	10	11	7	10			
1312	4	•	•	4	13	15	8	4
1320	7	4	6	6	7	4	27	22
1320	25	30	13	12	9	11	•	14
1334	4	10	7					
1452					٠,	10	5	7
1454	4	4	4	5	í	.,	7	13
1664	23	30	42	44	30	25	14	7
1672	Ĭ	4	4	•	-	2	•••	,
1741		5	7	12	18	12	_	
1748	5	11	16	21	27	20	7 20	4 17
1774		9	7	1	47	3	20 5	9
1784	ě	,	•	•	•	•	,	7
2044					4	4		
2048	13	•	14	17	24	10	14	•
2665		2						
2472	14	28	2 57	2 70	4 104	4	1	12
2600	127	71	5/ 54			111	134	143
	147	71	70	39	7	. 2	1	
3223								0
3224	1	1	1	1	0	4	1	2
3232	•	3	4	7	7	i	7	12
3240	5	5	4	4	0	-	•	•

```
COLLECTED AT: 03:39:20.2 13 AUG 84
```

EMERGY(KEV) = 0.27048E-07 +CM-2 + 0.54313E00 +CM +0.61837E01 PEAK STATISTICS- 1.00 HIN WIDTH- 6 HAX WIDTH- 8

ROIS 1 FROM 83.3 KEV TO 90.9 KEV
PEAK AT 88.8 KEV FUHN= 1.3 KEV
INTEBRAL= 6368 RATE= 6.3 CP8
AREA= 53 ERR= >>>>I CD-109 AT 88.0 KEV 0.16298E-02 UCI NP-237 AT 86.5 KEV 0.49726E-03 UCI

ROIS 2 FROM 708.5 KEV TO 724.8 KEV
PEAK AT 716.5 KEV FUMM= 8.3 KEV
INTEGRAL= 21262 RATE= 21.2 CPS
AREA= 19309 ERR= 0.92

Cs137 661.66

ROIN 3 FROM 1264.8 KEV TO 1282.1 KEV PEAK AT 1273.4 KEV FUHH= 8.4 KEV INTEGRAL= 11569 RATE= 11.5 CPB AREA= 10843 ERR= 1.12

MA-22 AT 1274.5 NEV - 0.7097E-01 UCI C. 60 1173.21

RGIN 4 FROM 1438.1 KEY TO 1454.0 KEY

PEAK AT 1444.9 KEV FUNN- 8.4 KEV
INTEGRAL- 7437 RATE- 7.4 CP8
AREA- 9503 ERR- 1.02

C. 60 1332.47

CHANNEL	•				BATA			
142							339	327
144	277	332	346	400	343	350	414	514
152	575	554	541	505	521			
1293						75	47	55
1274	74	85	137	367	754	1241	1464	1430
1304	1302	1116	1057	1037	1081	1039	1073	1277
1312	1460	1585	1419	778	469	177	77	42
1320	54	52	44	42	,	•••	••	
2317					•	13	31	37
2320	38	53	54	87	203	353	551	704
2328	770	724	675	611	547	- 500	575	619
2336	477	738	804	705	587	345	183	69
2344	41	23	16	23	20	13		
2636					•	5	10	10
2640	21	34	75	157	277	433	574	631
2648	422	585	537	472	519	487	537	573
2656	407	661	620	484	357	181	70	17
2664	10	2		0	2	2	. •	• • •
		•	•	•	•	•		

APPENDIX C.3 GAMMA SPECTROSCOPY LOG FROM LEHR SITE

A portable gamma spectroscopy system consisting of a Canberra Series 10 multichannel analyzer and a high purity Germanium solid state detector was used at the LEHR site for both in-situ and preliminary measurements. This was the first field trial of this equipment, and some problems with data retrieval from magnetic tape storage were experienced. These problems have not been completely solved at the time of release of this report. It should be noted that the lack of this data has no impact on this report as the data was duplicated by gamma spectroscopy at the Rockwell Canoga Park facility.

Rockwell International

Energy Systems Group

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APPENDIX C.4 RADIOCHEMICAL ANALYSIS DATA FROM EAL CORPORATION

In order that very small quantities of radioactive materials may be detected and measured, field measurement techniques must be abandoned and samples must be taken to a specialized laboratory. A contract was let to EAL Corporation (formerly Tracer Lab) in Richmond, California, for these analyses.

The following section reprodces the report received from EAL and includes a graphic analysis of the data.

Radium-226, Strontium-90, Carbon-14, and tritium were found in the samples as noted.

EAL Corporation

Thermo Electron

1. 1

2030 Wright: Avenue Richmond: California 94804 (415) 235-2633 (TWX) 910-382-8132

19 September 1984

Ref: Rockwell International P.O. No. 485-124-2KX
EAL W.O. No. 25-3000

Mr. David Speed Rockwell International Energy Systems Group 5000 DeSota Avenue Canoga Park, CA 91304

Dear Mr. Speed:

Enclosed are 14 C, 3 H, 226 Ra, 90 Sr and 24 Pu results of soils and sludges sent to us for analysis on the above purchase order.

The ¹⁴C and ³H determinations were made by combustion and liquid scintillation counting. Radium-226 was determined by Ge(Li) count. For ⁹⁰Sr and ²⁴ Pu determination, 1-gram each of the ashed material was completely dissolved by HF-HCl-HNO₃ treatment. A known amount of yttrium carrier was added to the dissolved sample and yttrium (the carrier as well as yttrium in equilibrium with ⁹⁰Sr in the sample) we extracted with HDEHP at pH 1, back extracted with 12 N-HCl, chemically purified by fluoride, hydroxide, oxalate steps and converted into oxide. The yttrium oxide was weighed and counted on a low-background β^- counter. The ⁹⁰Y decay data was processed by least square analysis, corrected for chemical yield, sample self absorption, aliquot and ⁹⁰Y ingrowth and decay.

A known amount of ²³⁶Pu tracer was equilibrated with the dissolved sample and plutonium was radiochemically purified. Plutonium-241 was determined by liquid scintillation counting in one half of the purified plutonium extract. From the other half, plutonium was electroplated on a stainless steel disc and the disc was subjected to alpha spec analysis. Plutonium-241 in the sample was calculated from the alpha spec and LSC counting results. The results of the analysis are given in pCi/gram cample.

Please call me if you have any questions.

ry truly yours,

Dinkar P. Kharkar, PhD Manager, Nuclear Projects Nuclear Science Department

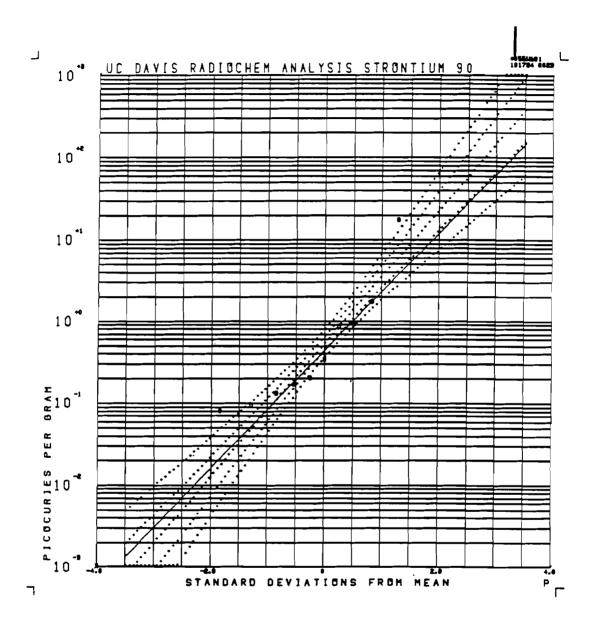
DPK/ss

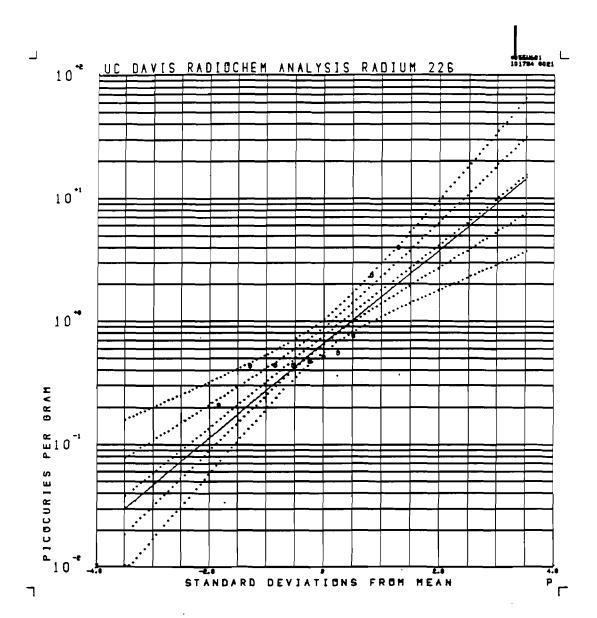
AI-DOE-13504 345

THELE 1 AMALYSIS OF 8 SAMPLES FROM ROCKWELL INTERMATIONAL

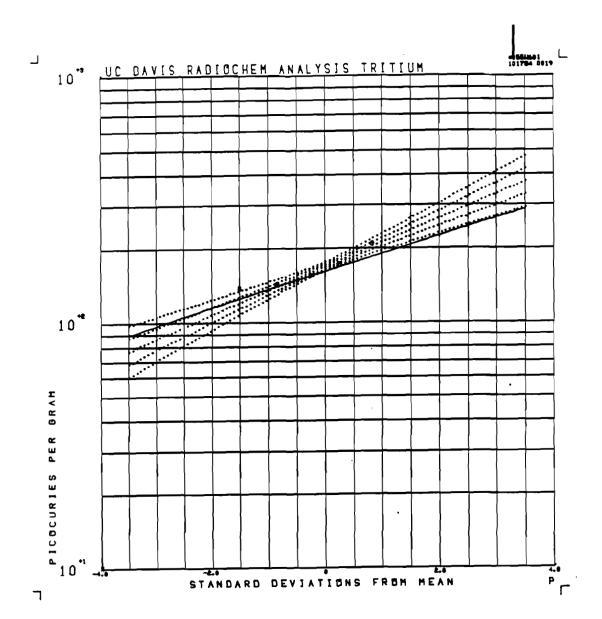
		Customer	EAL	14C	H [_]	226 Ra	905r	24 1 Pu
		Sample Nos.	Dissolution No.		pC1/gram	± 1 0 (2)		
u 9. 6	55+	4 44 20 50	50 8-16	<16	142 ± 16			
42 6 42 13		10	50 8-17	29 ± 48	20 8 ± 56			
4	🛆	24 See 2 2 3 3 6 7	5 08-18	<19	154 ± 44			
och 13	ЮĦ	39 · ·		$1,160 \pm 7$	171 2 14			
de 141	547	43 2 8	508-20	794 ± 4	137 ± 14			
		81 - 4 - 5 - 5	508-1			0.204 ± 19	0.334 ± 16	< 50
		82	5 08-2			0.425 ± 16	0.079 ± 60	
		83	508-3			0.431 : 13	1.71 ± 4	
		86				0.754 ± 11	0.095 ± 56	
		87	508-5			0.550 ± 13	0.13 ± 42	
		88	508-6			0.507 ± 11	0.17 ± 27	
		91 P > 2	508-7			0.469 ± 17	0.20 ± 62	
		106 : 5 2 15	50 8-8			3.94 ± 3	0.909 2 6	
		112 1				0.431 ± 12	0.352 ± 6	
		134 हार्केट कर्न करन	50 8- 10 .					< 50
		135 2 76- 43	508-11					<50
		136 Ra						< 50
		144 Tares of my - 3	508-13			2.35 ± 5	17.3 ± 2	
		Blank (a)	508-15	<16	< 25		<0.20	<50

⁽a) Blank is pCi/sample.

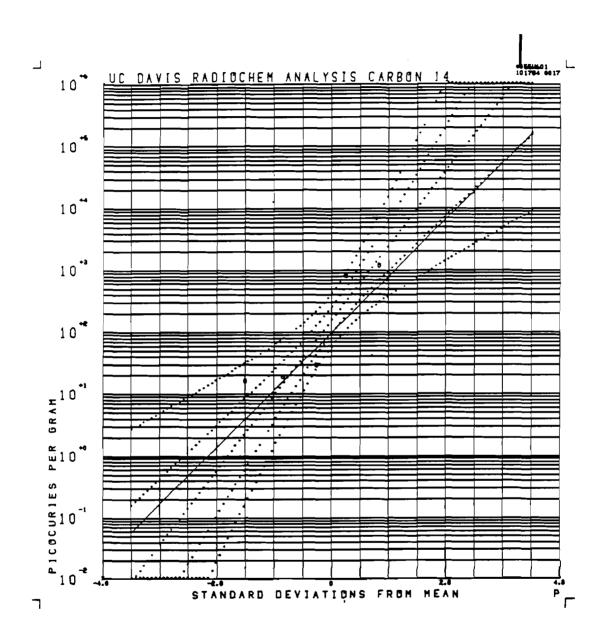




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APPENDIX D

RADIOMETRIC ANALYSIS METHODS

1.0 SURVEY SCOPE AND PROCEDURES

1.1 SURVEY SCOPE

The scope of this survey was to perform radiological surveys for average total alpha and beta contamination, removable alpha and beta contamination, and gamma radiation measurements on a representative portion of the LEHR site. Statistical sampling was used because of the scope of the project and its proven usefulness in describing site conditions. Areas also were surveyed and biased as to sampling frequency on the basis of likelihood of contamination. This is the appropriate method for the desired sampling, as in our experience, these areas has been found to be most representative of the radiological conditions of an industrial facility. No data was obtained from the interior of any buildings, the interior of exhaust systems before HEPA filters or active drain systems, or from the interior of any of the sealed glove boxes.

1.2 SURVEY EQUIPMENT

1.2.1 Instrumentation

Instruments used for radiological inspection consisted of field survey instruments, portable scaler counting systems, and nonportable, laboratory-grade gamma spectroscopy systems (located at Rockwell in Canoga Park, California).

1.2.2 Identification

Each radiological instrument is identified by an ESG property number or metrology number for traceability of NBS referenced calibration and results. For separable devices, such as a scaler and detector probe, a metrology number is assigned to each probe.

1.2.3 Field Instruments

Field instruments were used for measurement of average total (fixed and removable contamination) and hot-spot measurements. The following types of field instruments were used for the survey of the LEHR facililty:

1) Technical Associates Model FS-8 Automatic Recycling Scaler

The Technical Associates FS-8 is a five-decade scaler that can be used with a wide variety of radiation detectors. Provisions are made for using preset time of 0.1 to 9999.9 seconds or preset counts in the range of 1 to 99,999. High voltage is adjustable by a lock 10-turn potentiometer located on the front panel. The FS-8 also has an adjustable audible and visual alarm and an audible count rate indication. Both a low-battery indicator and a count overflow indicator are provided.

This instrument was used with one of two probes described in the following section to measure average total alpha and beta contamination.

a) Ludlum Model 43-5 Alpha Scintillation Probe

This probe has an active surface area of 63 sq centimeters and a nominal efficiency of 4 dpm/cpm. These detectors are sensitive only to alpha particles. These particles must have an energy of approximately 1.5 MeV at the window surface.

b) Ludlum Model 44-9 Geiger-Mueller Pancake Probe

This probe is used for the detection of beta particles and has an active surface area of 20 sq centimeters. Nominal efficiency is 10 dpm/cpm. Background will vary greatly with natural background radiation but should be in the range of 30 to 120 cpm. This detector will also detect alpha particles with an energy greater than 3 MeV. It will also detect gamma-emitting radionuclides distributed within materials as a result of kinetic electrons produced by gamma interactions within that material and/or the material of the probe.

2) Ludlum Model 12S HicroR Heter

This instrument is used for the detection of gamma radiation above the energy of 60 keV. As such, it cannot be used to detect the low-energy penetrating radiations from plutonium. This instrument uses a l in. by l in. NaI(TI) scintillation crystal with photomultiplier tube. It is calbrated according to the manufacturer's recommendations to cesium-137 gamma radiation. This meter has a scale of 0-3 micro R/hr and range-switched multipliers of XI, XIO, XIOO, and XIOOO.

3) Nuclear Measurement Corporation Model ACS-77 Automatic Counting System

This system employs a 2-in.-diameter planchet transport system and a 2-in. 2 PI geometry gas-flow proportional detector. This detector is operated at a voltage of 1600-1800 volts. This is a windowed detector with a window thickness of 180 micrograms/sq. centimeter. This enables the system to detect both alpha and beta particles.

Alpha and beta counts are automatically identified and separately indicated. Counting time is selectable from 0.1 to 9999 minutes. The alpha efficiency factor is nominally 3.3 dpm/cpm with a background of 1 cpm or less. The beta efficiency factor is nominally 3.2 dpm/cpm with a background of approximately 25 cpm.

4) Ludlum Model 2200 Scaler with Eberline Sodium Iodide Gamma
Probe-

The Ludlum 2200 scaler is a six decade counter coupled to a single channel analyzer (SCA) electronics package. Individual 10-turn potientiometers allow adjustment of gain, the shold of discrimination and width of the window. For most gross gamma measurements, the window is opened to full width and the discriminator is adjusted to just above the noise floor of the detector.

The Eberline Sodium Iodide Gamma Probe is an assembly consisting of a $2^m \times 2^m$ NaI crystal and a ruggedized photomultiplier tube mounted in an aluminum housing.

4.2.4 Laboratory Instruments

Laboratory instruments were used to measure soil contamination (gamma) obtained on site. Due to the great weight of the shielding, this equipment remained in Canoga Park, California, at the Rockwell International facility.

4.2.5 Instrument Calibration

Maintenance and calibration of all battery-powered (field instruments) systems are performed on a quarterly basis by the Inspection and Test

Department. Batteries may be replaced without recalibration. Laboratory instruments are serviced and calibrated on a biannual basis.

Daily qualification tests are performed by Radiation and Nuclear Safety. Prior to each use of an instrument, the calibration label is checked to assure that the instrument is in current calibration.

4.2.6 <u>Instrument Qualification</u>

Instruments will be checked prior to their first use each day. The check will consist of a background reading and a reading obtained from a standard source and source-detector geometry. Those that indicate a significant change or are erratic or otherwise malfunctioning must be repaired and recalibrated before further use.

4.3 SURVEY PROCEDURE

4.3.1 Selection of Sampling Points

4.3.1.1 Partial Inspection

As the task of the ESG survey team was to provide an overview and not a comprehensive, radiological survey of the LEHR facility, a partial inspection plan was used. The aim was to provide a statistically significant number of survey points for each area which would represent a reasonable statistical "population." For Gaussian statistics, this number of samples, "n," should be chosen so that n 20 for each population. Using this guidance, approximately 2% of the floor area of suspect structures was sampled.

4.3.1.2 <u>Siting</u>

Survey points were selected on a random-biased basis. Due to instrumentation considerations and time constraints, it was decided to concentrate the

statistical sampling on the floor surfaces only. It has been our experience that the floor (or ground) is the most appropriately conservative population to sample in cases such as this. (Walls and ceilings tend to harbor less contamination than floors.) Sampling points were selected randomly, but biased by the expert judgment of the surveyors so that many "suspicious" spots such as an area immediately outside the dog pens and areas of the floor which would be difficult to clean on an ordinary basis were sampled. Survey points were also sited in the traffic patterns in order to determine the occurrence and extent of tracking contamination.

4.3.2 Measurement Procedures

The following procedures were used to make the measurements related in this document. These procedures have been employed by ESG and have proven to be extremely effective for documentation for release for unrestricted use of facilities previously contaminated with radioactive materials: These procedures have been accepted by the U.S. NRC for this purpose.

4.3.2.1 Average Total Alpha and Beta

- 1) Identify the spot to be surveyed.
- 2) Identify the area by painting an outline around a 1-meter-sq area.
- 3) With a portable scaler (Technical Associates FS-8 or equivalent) set for a 5-min count time, use an alpha and a beta probe set in a holding device to uniformly scan the marked area. The audio indication should be on so that the surveyour can detect any "hot spots." These hot spots are to be resurveyed later.
- 4) Record the location and total counts for alpha and beta.

5) The total count is converted to activity in dpm/100 sq cm by:

Activity = [(C-B)/5][E(100/A)]

Where C = total counts in 5 min

B = total background counts in 5 min

E = efficiency in dpm/cpm

A = probe sensitive area.

4.3.2.2 Removable Alpha and Beta

- 1) Identify 1-sq-meter area to be surveyed (after the total activity measurement is made).
- 2) Using a Whatman 540 filter paper (2.4 cm diameter), wipe a "Z" pattern, with legs approximately 6 in. long so as to sample removable contamination from an area of approximately 100 sq centimeters.
- 3) Place smear paper in a properly labeled note card "book" for storage and transport until ready for counting.
- 4) Count smear paper for radiocativity using a gas-flow proportional counter (NMC Model ASC-77 or equivalent) for 5 min.
- 5) Record the location, total alpha count and total beta count on an H&RS Survey Report Form.
- 6) The total counts are converted to dpm/100 sq centimeters removable surface activity by:

Activity = [(C-B)/5]E

Where C = total counts in 5 min

B = total background counts in 5 min

E = efficiency in dpm/cpm

4.3.2.3 "Hot Spot" Measurements

- 1) Survey suspect areas with a count rate meter such as a Ludlum Model 12 with a appropriate probe to determine the location of maximum contamination.
- 2) Count the area of maximum contamination for 1 min using a portable scaler as previously noted.
- 3) Record the location and total count on an H&RS Survey Report form noted as a "HOT SPOT."
- 4) The total count is converted to activity in dpm/100 sq centimeters by

Activity - (C-B)[E(100/A)]

Where C = total counts in I min

B = background counts in I min

E = efficiency in dpm/cpm

A = probe sensitive area.

4.3.2.4 Gamma Radiation Measurements

4.3.2.4.1 Micro R/Hr Measurements

1) Locate the area to be measured; mark on appropriate map.

- 2) If the area is a floor grid, hold the instrument (Ludlum Model 12-S or equivalent) approximately I meter from the floor surface and scan the grid. Record the reading obtained in the center of the grid and the maximum reading obtained, it applicable.
- 3) For other measurements, such as traps, glove boxes, and "hot spots," record the average and maximum readings on the appropriate forms.

4.3.2.4.2 Gross Gamma Measurements

- 1) Hold detector 3 feet above area of interest and count for one minute. Record.
- Lower detector into hold just below surface, count for one minute and record data.
- 3) Repeat procedures at 5-foot intervals to the maximum depth and record data.
- 4) Starting at the bottom with the detector on, slowly scan the hole all the way to the top, observing the count rate meter. If a "hot" spot is detected, take a one minute count at that level and at one foot below and above that point. Record Data.

4.3.2.4.3. Gamma Spectral Scan

- 1) Place sample jar on shield GE detector.
- 2) Collect data for 1000 seconds or more.
- 3) Identify energy peak by kev.
- 4) Record data on typewriter printout.
- 5) Identify significant isotopes present by their characteristic gamma peak.

The purpose of statistical analysis is to convert a large amount of data into a manageable amount of understandable information. This process can involve a variety of mathematical techniques, the simplest being the determination of an average (or mean) value for a given set of data. This simple determination is improved upon be also calculating the standard devation of the data about the mean, which gives an estimate of the variability of the data. In many cases, this variability represent variations both in the characteristics being measured (say, average alpha activity in I m²) and in the measurement (due to random fluctuations in the detector count rate and background).

The significance of these quantities (mean and standard deviation) depends upon the distribution assumed for the data. Sometimes there is a theoretically known distribution for a particular measurement process, such as the binominal or the Poisson distribution for counting radioactivity. These distributions are relatively well approximated by the Gaussian, or normal, distribution. In fact, the Gaussian distribution approximates the distribution of many different kinds of measurements and for simplicity is generally assumed to be the proper distribution. The Gaussian distribution is frequently seen in the form of a "bell"-shaped curve, with most values occurring near the mean value and fewer and fewer values existing at increasing distance from the mean, both greater than and less than the mean.

However, it is difficult to derive this bell-shaped curve from experimental data unless the data are specifically selected to demonstrate the curve, and deviations from the distribution are difficult to see. A better version is the so-called "cumulative probability function," which forms an "S"-shaped curve when plotted in the usual manner. This can be further improved by adjusting the abscissa (the "X"- values on an X-Y graph) so that the S curve becomes a straight line. This is a standard statistical technique and is the basis for special graph paper used for probability analysis of data. The parameters of the Gaussian distribution (the mean and standard deviation) are determined by the usual calculational methods:

$$mean = X = \frac{X_i}{N}$$

$$\frac{(x_i - \overline{x})^2}{\text{standard deviation}} = S = \frac{(x_i - \overline{x})^2}{N - 1}$$

where X_{i} represents the individual data values, and N is the number of points.

This method is the basis for the figures presented earlier in this report, where the measured values are plotted against the distance from the mean value, using the standard deviation of the assumed Gaussian distribution as the unit.

Where the data are not well represented by a Gaussian distribution (and this is true in most of the cases), the departure is readily apparent: the data points do not lie along the straight line representing the Gaussian. In most cases, this departure takes a single typical form. Much of the data forms a nearly horizontal straight line with the balance forming another nearly straight, steeply sloping line.

This can usually be interpreted as showing a large number of uncontaminated locations where the variability is due to random fluctuations in the measurements themselves, with the balance being locations that have more or less significant residual radioactivity.

In the present report, this analysis has not been extended to provide a sampling inspection test as there was insufficient data for a confident analysis. This uses a standard quality control technique called inspection by variables, in which the distribution of measured values is used to predict the probability that other, unmeasured values would exceed a specified limit. The

standard test method requires calculating the mean (X) and the standard deviation (s). Then, depending upon values chosen for certain parameters that affect the performance of the test in accepting bad lots or rejecting good lots, the necessary number of samples is determined and a multiplier, k, is computed so that the inequality

$$X + ks L$$

where L is the acceptance limit, representing an acceptable lot. In the present application, the term "lot" applies to a major facility.

The parameters used in this test are those recommended by the State of California, Radiologic Health Section, for release of a facility for unrestricted use. These are the so-called "consumer's risk" (or β) and the "lot-tolerance percent defective" (LTPD). The values recommended for these are β = 0.1 and LTPD = 10%. This means that, if a lot just passes the acceptance test, there is one chance in ten (0.1) that 10% of the total number of locations in the facility sampled would have residual radioactivity exceeding the limit.

The usual manner of applying this inspection test is to use tables giving values of the sample size (N) and multiplier (k) for the selected values of β and LTPD. In the present application, the number of measured values (N) in each lot was used to compute k, and this value was used to calculate X + ks. The computation of k is somewhat complicated, but once programmed for the computer as part of the data analysis program, the complication is no obstacle to its use:

$$k = \frac{K_2 + K_2^2 - ab}{a}$$

with a =
$$1 - \frac{K_B^2}{2(N-1)}$$

and b =
$$K_2^2 - \frac{K_B^2}{N}$$

The value of K_2 is that for the variable of a Gaussian distribution corresponding to the LTPD value, and the value of K_{β} is that for the Gaussian variable corresponding to β . In this case, both these values are 1.282.

Inasmuch as the limit for gamma exposure rate is not well defined and is very sensitive to the great variation in environmental radiation, this complete analysis was not applied to the gamma measurements. Instead, the values were plotted against an assumed log-Gaussian (log-normal) distribution and the test was not calculated. In each case, the significantly high readings can be judged by looking at the plot.